Building Occupant Environmental Behaviour (BOEB) Model for LEED-certified buildings

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ABSTRACT

Energy consumption in most residential buildings became a critical issue that should be focused upon to move towards a green built environment and mitigate global warming. Green agencies are actively practicing in different regions of the world while hoping to achieve carbon emission reduction. Unfortunately, there is still a performance gap between as-designed and actual energy consumption after operation. Occupant behaviour accounts as one of the major reasons behind this significant uncertainty. Little is known about how the occupants of these buildings cause the performance gap. This micro-focus has therefore created a research opportunity to investigate in detail the LEED-certified building occupant environmental behaviour to gain a better understanding on how to improve their behaviour and the existing uncertainty in order to achieve potential energy savings.

The findings in this research rely on data collected from four LEED-certified buildings in the UAE. The data analysis for the main research study was mix method including quantitative (survey with 203 occupants) and qualitative (interview with 10 occupants and 5 operators). After that the data was analysed using Structural Equation Modelling (SEM) technique to investigate the interrelationship among three unobserved variables which are occupant Attitude, Knowledge and Behaviour (AKB). The Building Occupant Environmental Behaviour (BOEB) model was then developed. The development of the model was based on the literature review and the best fitting structural model confirmed through SEM, together with inclusion of motivational factors found in qualitative analysis in this study. Finally, academic researchers and industry professionals in the UAE and Canada validated the developed BOEB model in order to review the applicability of, and barriers to, this model. Such model can be used by LEED policy makers, industry professionals, and governmental authorities to promote better environmentally-friendly behaviour to potentially bridge part of the existing energy performance gap.

DEDICATION

I would like to express my sincere appreciation to my primary supervisor Dr. Mehreen Gul who impressed and encouraged me with her knowledge and intellectual integrity. Without her kindness, insight, and constructive feedback, I would have not been able to accomplish this research study. My sincere thanks also go to my secondary supervisor Dr. David Campbell for all his professional advices. I am also grateful to Professor Ming Sun and Dr. Dough Harris who spent their time at the earlier stage of my research study. A very special appreciation goes to Dr. David Kelly for his valuable feedback at the final stage of my PhD thesis.

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DECLARATION STATEMENT

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This thesis contains one or more multi-author published works. In accordance with Regulation 6 (9.1.2), I hereby declare that the contributions of each author to these publications is as follows:

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CHAPTER 1 - INTRODUCTION

1.1 RATIONALE

It is true that the construction industry is responsible for majority of global energy consumption (Straube, 2006). An average of 40% of the energy used worldwide was consumed to maintain healthy and comfortable indoor environments for occupants of residential and commercial buildings (D'Oca et al., 2017; Sun & Hong 2017). The building sector in general is responsible for almost half of the total energy consumption in Europe and of half the energy consumed in the United States (US EIA 2013). China's building sector surpassed the US which was so far the largest consumer of energy in the world, with carbon dioxide emissions in 2010 (Hong et al., 2015; Gul & Patidar 2015).

Energy saving is currently the hot topic within the construction industry. Decreasing energy consumption is a critical component of meeting carbon reduction commitments, which, in turn, can have very positive impact on the reduction of global warming (Janda, 2011). Concerned governments, as well as the Green agencies have taken measures to facilitate sustainable construction. As the building industry is growing significantly, the energy consumption in buildings is also growing rapidly. Global warming is causing both developed and developing countries to reduce energy consumption in the building construction sector. This energy consumption crisis is the reason for the growing concern and interest in providing environmentally-friendly alternatives to mitigate the negative and harmful effects of climate change and global warming. Green building guidelines have grown out of these concerns, and their popularity in providing green buildings in response to the increase in global energy awareness has risen dramatically.

Many countries have begun to adopt mandatory green requirements for their building developments and green rating systems have become increasingly adopted worldwide. Some of the most widely used rating systems include: i) Leadership in Energy and Environmental Design (LEED), ii) Building Research Establishment Environmental Assessment Methodology (BREEAM), and iii) Green Globe Canada (Papadopoulos & Giama, 2009), and other well-recognised rating systems are: iv) Green Star Australia, v) Building Environmental Performance Assessment Criteria (BEPAC) Canada, vi) GB tool Korea and vii) Comprehensive Assessment System for Built Environment Efficiency (CASBEE) in Japan (Ghaffarianhoseini et al., 2013). The most popular green agencies for buildings in the

United Arab Emirates (UAE) are the LEED mostly used in Dubai and then BREEAM mostly applied in Abu Dhabi. The Emirates Green Building Council (EmiratesGBC) was formed in 2006, with the goal of advancing green building principles for protecting the environment and ensuring environmental sustainability in the United Arab Emirates (EmiratesGBC).

LEED was developed by the U.S. Green Building Council, including evaluation characteristics such as: a) location and transportation b) sustainable sites, c) water efficiency, e) energy and atmosphere, f) materials and resources, g) indoor environmental quality, h) innovation and i) regional priority. LEED is very user-friendly and one of the most recognised rating tools based on credits achieved. From 1994 to 2006, LEED grew from one standard to a very comprehensive system covering all aspects of the construction process (USGBC, 2012). Green building rating systems, such as LEED, BREEAM and the others cited above, encourage the provision of features such as natural light, natural ventilation and high air quality, as well as control their environment by considering indoor environmental quality (IEQ) before occupancy to help design more sustainable buildings (Leaman et al. 2007). All the sustainable design rating systems grant credits for actions intended to improve IEQ at the preoccupancy level. Undoubtedly, human-induced stressors have caused changes to our natural environment and the ecosystem. Building occupant environmental behaviour plays a critical role in the built environment (Janda, 2011) and this factor is one of the important parts of sustainable/green buildings that has been widely overlooked.

All green rating systems mentioned above have very limited focus on occupant behaviour monitoring system during a building’s operation. Evidence exists (Birt & Newsham, 2011; D’Oca et al., 2017) to support the fact that by improving occupant behaviour, energy consumption can be reduced by 8%-15% in all types of buildings, resulting in lower carbon emissions. The broad impact of human dimensions on energy use has been both noted and accepted, but there is also a need to meet the internationally agreed 2020 and 2050 energy and greenhouse gas reduction goals (D’Oca et al., 2017). Therefore, enabling buildings to become environmentally, economically, and socially sustainable (AboulNaga & Elsheshtawy, 2001). The importance of environmentally-friendly behavioural improvement is evident in the fact that many buildings using new technology-oriented systems fail to meet their “as designed” performance expectations (Turner and Frankel, 2008). At least, part of this performance gap is attributable to occupant unforeseen usages of these green/LEED-certified buildings and their equipment.

To date very few Post Occupancy Evaluations (POEs) surveys in green buildings have been reported. Many of the POEs are just simple case studies of small projects, which made it difficult to generalize the conclusions regarding occupant behaviour and its interrelationship with corresponding energy use (Birt & Newsham, 2011).

This research will first try to investigate how better we can understand occupant behaviour through more intensive POEs including both surveys and interviews. After that it will try to find out how to improve building occupant environmental behaviour by reviewing the interrelationship between their environmental Attitude, Knowledge and Behaviour (AKB) to achieve energy savings. This study will explore whether the occupants have the required knowledge and/ or motivations to change their behaviour.

1.2 RESEARCH JUSTIFICATION AND BACKGROUND STUDIES

The climate of the UAE presents important challenges to reduce energy consumption in buildings, due to its hot and arid climate with regular high levels of solar radiation and humidity. Over the past 20 years, the UAE had rapid growth, which has resulted in a large and growing stock of modern high-density buildings. Today the UAE has become one of the world's biggest per capita air polluters, it has been listed as a country with the highest per capita fossil fuel consumption and carbon dioxide emission rates worldwide (AboulNaga et al., 2001). In addition, because of increasing tourism, together with average population growth, the UAE's demands on natural resources have also increased in terms of water and energy consumption, in addition to a massive production of waste.

This phenomenon is especially evident in the UAE where most of the high-rise buildings have been constructed in the last 20 years. Most of these buildings were not designed to LEED standards, to passively minimize the negative effects of this extreme climate, but rather to tackle the climate's challenges via the high usage of mechanical solutions, particularly air conditioning. In the UAE, around 80% of a building's electricity demand is for cooling. Outdoor air temperature in the UAE is above 25°C for 75% of the typical working hours, relative humidity is above 60% for more than 20% and solar radiation is in excess of 893 W/m^2 for more than 15% of the year. These environmental conditions mean that the mechanical cooling by air conditioning is required to maintain indoor comfort levels for most of the year (Shanks & NezamiFar, 2013). In view of the recent prioritising of sustainable development pathways and green buildings, along with the related implications of climate change, it became necessary to identify a suitable rating system. It is reasonable to conclude that the UAE construction industry practices were not sustainable when they were created, especially when compared to today. Investors concentration were mainly in obtaining the quickest returns on their investments; a focus that ultimately led to the downfall of the UAE's construction sector. Studies (Radhi & Fikiry, 2010; AboulNaga et al., 2001) have revealed the high energy consumption and carbon dioxide emissions of most existing commercial and educational buildings in Dubai and Abu Dhabi when compared to international benchmarks.

The energy performance of buildings in the UAE is nothing better than the buildings located in the European and North American countries (AboulNaga et al., 2001). Based on statistics that show 43% of the carbon dioxide production is due to electricity usage within buildings in the UAE and only 4% is caused by the direct emissions of buildings (Radhi & Fikiry, 2010). Carbon emissions in the UAE is 22.2 metric tons per person on annual basis, due to the increased use of buildings cooling systems, as originally noted by Maceda (2003). The UAE's government has recognised the importance of energy efficiency and has focused on the building sector as the main energy consumer. Thermal insulation and green building codes have been applied in both Dubai and Abu Dhabi; however, there is no model for analysing the impact of these codes on the reduction of carbon dioxide emissions (Radhi & Fikiry, 2010).

In 1991 the UAE established a non-government organization (NGO) called the Emirates Environmental Group for the purpose of promoting sustainability in the UAE (Salama & Hana, 2010). After that, the number of buildings in the commercial stock, in both the growing and newer buildings is increasingly adopting energy efficient strategies to address demands for cooling. These changes in newer buildings are influenced by the national drive towards sustainability, and particularly the introduction of green building regulations in 2003 when the Dubai municipality enforced Degree 66 as an energy saving approach. This saving was to be achieved by improving the building insulation and glazing systems. Following that, the Estidama programme was launched and the Emirates Green Building Council

(EmiratesGBC) was created in 2006 in order to ensure sustainability. Since then the demands and attitudes of the UAE's residents have improved significantly towards sustainability achievement within the built environment. The Urban Planning Council (UPC) was also established in Abu Dhabi in 2007 for enforcing building regulations. As for high-rises that were constructed before these new green building regulations, the majority of them were built with no consideration for energy saving requirements (Hamad et al., 2010). The UAE has led the region in climate change policy since its initial signing of the Paris Agreement in 2015 and has maintained its commitments in subsequent years. This focus can be seen in the commitment of 27 percent of their energy from clean sources by 2021, increasing to 50 percent by 2050. In 2018, the UAE has welcomed the 'rule book' laid out as part of a COP24 deal and has urged the international community to further commit to the fight against global warming. In a complementary move, the UN and international climate change organisations are also calling for more to be done (Al-Wasmi, 2018).

Harsh weather conditions in the UAE, together with lack of consideration towards energy conservation and green practices over several years of early development identified the UAE as one of the top ten countries in electricity usage and the second in carbon dioxide emission per capita (Hamad et al., 2010). The UAE has promoted sustainable development mainly after the 2008 economic crisis, it was prescribed that construction sector in the UAE should be in line with the international sustainability standards (Landais, 2007). These initiatives taken towards sustainable practices are at their very early stages (Maceda, 2013), but it is true that the UAE has taken these issues seriously, especially in the construction sector while the UAE has chosen sustainability as an important factor to bid for EXPO (EXPO2020-Dubai). Therefore, sustainability became one of the targets in 2013 (Maceda, 2013; UAE Cabinet, 2011).

The Abu Dhabi Planning Council introduced ESTIDAMA in 2008, involving guidelines for both the designing and operating of sustainable buildings (Ward, 2009). The UAE has the greatest number of LEED-certified buildings as compared to the projects in the Middle Eastern and North African countries. BREEAM was also launched in Abu Dhabi-UAE, in accordance with the local hot and arid climate conditions (Ward, 2009).

There are some remarkable projects in the UAE, such as Masdar City; a carbon-neutral and sustainable city powered by renewable energy technologies under the supervision of

Government-owned Mubadala Development Company for Abu Dhabi vision 2030. Innovative designs and technologies such as: i) solar panels, ii) wind turbines, iii) recycled glass, iv) high temperature plasma torch systems and v) non-toxic plastic products are used to promote a safer environment in the Masdar City Project (Masdar City, 2013). Another example of a well-designed building with a green approach will be the 59 floor Rotating Tower as a green architecture project, which produces its own energy from its wind turbines and solar panels (Fisher, 2008). One of the good examples of successful design, which can be considered as a retrofitting solution to lots of existing towers, is '0-14/ Swiss cheese tower'. This initiative was designed by Rur Architecture-Resier and Umemoto which has a double-skin façade constructed from 40cm thick perforated concrete. The one-meter space between the shells (outer perforated concrete and inner glazing system) creates a chimney effect which cools the building as hot air has room to rise, thereby providing natural ventilation. This passive technique reduces the energy consumption for HVAC systems by 30% (Welch, 2019).

1.3 RESEARCH MOTIVATION

The original motivation for this study was generated due to the researcher observing the people's lack of concern and care with regards to saving energy in their homes while she resided for more than 10 years in the United Arab Emirates (UAE). Although the energy bills were still expensive, when compared to many other countries, they were affordable to residents in the UAE due to their high-income levels; a condition which caused them to have little or no concern about their energy usage. This situation was also related to the fact that there was insufficient pressure or motivation from authorities to modify resident's energy consumption, as well as lack of green rating systems and industry professionals for promoting positive environmental behaviour. Even though there are initiatives in place in the UAE concerning green buildings (Ward, 2009; Maceda, 2013; UAE Cabinet, 2011; Gulf news, 2017), there is still a need to further improve building occupant environmental behaviour to minimise the energy performance gap and achieve potential energy savings. Therefore, this research will investigate how to improve occupant environmental behaviour to achieve energy savings. It will explore whether the occupants have the knowledge to change their environmental behaviour and if their beliefs and attitude can lead them towards greener behavior. To fulfill the mentioned purpose, the interrelationship between occupant Attitudes, Knowledge and Behaviour (AKB) will be analysed.

1.4 RESEARCH PROBLEM AND HYPOTHESIS

The first and even second generations of LEED-certified buildings in the UAE are now occupied. A question that may be asked is whether these green/ LEED-certified buildings potentially deliver on their initial design purpose. Answering this question is difficult at present, with a few available POEs at post-occupancy phase by industry professionals. Most studies on energy consumption of LEED-certified buildings have concluded that an energy performance gap existed between predicted and actual energy consumption (Turner and Frankel, 2008). One of the key common factors is that the buildings may not be operated properly, when an energy knowledge gap exists between the industry professionals, building operators, and occupants. In addition to these considerations, occupants perform various actions to satisfy their needs in buildings; actions which negatively affect building energy consumption because those occupants do not always behave environmentally-friendly to achieve the energy saving potential of their buildings (Belafi et al., 2018).

The green building initiatives, such as LEED and many other good practices regulated by the UAE government, do not necessarily mean that a building occupant behaves in an environmentally-friendly fashion. There is clearly a need for further research to clarify this issue in order to bridge the gap between predicted and actual energy savings. One of the reasons is occupant behaviour. Therefore, the hypothesis that this research sets out to investigate is that:

"The occupants of LEED-certified buildings are not knowledgeable and motivated to behave environmentally-friendly".

If the research shows the hypothesis to be correct, then the LEED certification process needs to adapt to ensure that the occupants are knowledgeable and motivated so enabling them to behave in an environmentally-friendly manner. However, if the research refutes the hypothesis, then it means the LEED-certified building performance gap is not due to lack of knowledge and motivation for occupants to behave environmentally-friendly. Therefore, it is possible that there are other factors which cause the gap between the design and the constructed buildings actual performance such as: a) environmental uncertainties due to climate change, b) the use of synthetic weather data files, c) the less than satisfactory quality of building elements and workmanship and d) design flaws and mistakes.

1.5 RESEARCH AIM AND OBJECTIVES

The aim of this research is to explore how building occupant behaviour can be positively influenced and improved to achieve the potential energy savings in LEED-certified buildings. Such buildings can lead to energy savings but achieving this saving needs green and environmentally-responsible people who are properly educated and motivated to behave in an environmentally-friendly manner.

The following specific research objectives need to be accomplished:

1. To review the development of green buildings and evaluate the impact of occupant environmental behaviour on green buildings performance.
2. To review the existing occupant behaviour models and frameworks.
3. To understand occupant environmental behaviour and to investigate the interrelationships between their environmental Attitude, Knowledge and Behavior (AKB) within LEED-certified buildings.
4. To develop a Building Occupant Environmental Behaviour (BOEB) model.
5. To validate the developed BOEB model and demonstrate its applicability.

1.6 STRUCTURE AND OVERVIEW OF THE THESIS

This thesis is presented in eight Chapters:

- Chapter 1 presents an overall introduction to the study, including: a) the rationale, b) the research justification and the background studies, c) the research motivation, d) the research problems and the hypothesis, e) the research aim and objectives, and f) the structure and overview of the thesis.
- Chapter 2 presents a literature review which covers three main areas: i) the development of green buildings; ii) the performance of these buildings; and iii) the review of existing occupant behavioural models and frameworks. Such an approach ensures that this study builds on the existing body of knowledge gained from previous works in the relevant field.
- Chapter 3 explains the research methodology adopted for this study. It starts with comparing and reviewing different methodologies, as well as discussing the

suitability of the one adopted methodology for both the pilot and main research studies.

- Chapter 4 presents the results from the pilot study to confirm that not all green buildings have necessarily occupants with better environmentally-friendly behaviour than those in conventional buildings and therefore, there is a need to concentrate on LEED-certified buildings. After that, the results from data collected during both survey and interviews with LEED-certified building occupants and operators for the main research study are presented. The survey questionnaire and results are structured in five different sections such as: i) the occupant's background, ii) attitudes, iii) behaviour, iv) level of comfort and satisfaction as well as v) their knowledge. The main research study was conducted via a survey involving 203 occupants and interviews with 10 occupants and 5 building operators (BOs) within four LEED-certified buildings in the UAE.
- Chapter 5 presents the evaluation of the measurement model and structural model, which have been used as the baselines to develop the Building Occupant Environmental Behaviour (BOEB) model in Chapter 6. Structural Equation Modelling (SEM) technique was used. The findings presented in Chapter 5 provide an understanding of the interrelationships between different parameters, such as occupant environmental Attitudes, Knowledge and Behaviour (AKB).
- Chapter 6 describes the BOEB model, which has been initially designed based on the best fitting structural model and mainly developed based on this research findings in Chapter 4 and the literature review in Chapter 2.
- Chapter 7 explains the process of validation through expert's revision. Validators are asked to comment on the developed BOEB model's applicability and barriers as well as recommendations to help the researcher to improve and finalise the BOEB model. The final BOEB model is proposed at the end of Chapter 7 after considering required modifications through the validation process.
- Chapter 8 presents an explained assessment of whether the hypothesis is confirmed and if the aim has been met, as well as how each objective has been achieved. This Chapter also summaries the overall research findings and outcomes. The research strength, limitations, contribution, and avenue for future research are discussed in this Chapter.

CHAPTER 2 - LITERATURE REVIEW

2.1 SUSTAINABLE BUILDINGS

The word 'sustainability' comes from two stems: i) '*tenere'* - to hold and ii) '*sus'* - up. Sustainability is not only about the environment, but it also has socio-economic fundamentals as shown in Figure 2.1. The financial costs for constructing green buildings might be on the higher side than for conventional non-green buildings while such approach can save considerable amount of money by reducing their operational and maintenance costs. The motivation of builders, industry professionals, building operators, and occupants towards constructing sustainable buildings is crucial (Papadopoulos & Giama, 2009).

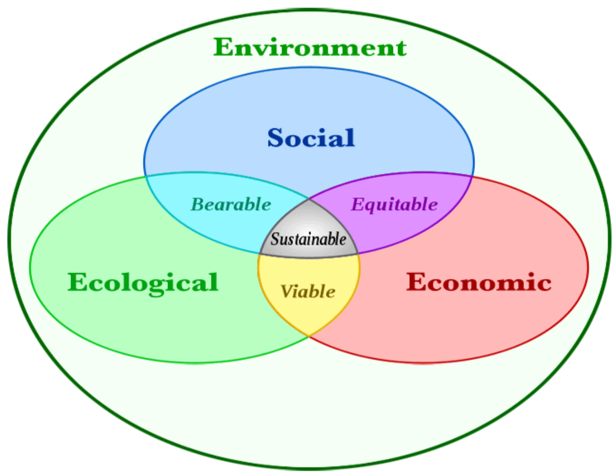

Figure 2. 1 Scope of sustainability (Adams, 2006)

An economic fundamental for the building owners is the motive of profit making throughout the lifecycle of their building (Freihoefer, 2012). However, the environmental element associated with those same buildings involves preventing harmful impacts on nature by minimising the consumption of natural resources, as well as reducing levels of pollution. The social element regarding those who occupy buildings has received much less attention than the issues of economic and environmental sustainability. The concept of 'social sustainability' includes: a) livability, b) human rights, c) human adoption, d) health and social equity, e) social support and responsibility, f) community development and resilience, and finally g) cultural competence (Adams, 2006).

Sustainability has become part of the culture in some cities due to the promotion of this term in the environmentally awareness strategies in 21st century (Ghaffarianhoseini et al., 2013). Green building is one of the measures that have been put forward to mitigate negative effects of the current activities on the society, economy, and environment. Over the last decade the subject of sustainable architecture became one of the most productive areas of study associated with the built environment (Yu et al. 2012). Buildings are the largest single energy-consuming and greenhouse gas emitting sources all around the world (Architecture 2030 guide, 2008). Ghaffarianhoseini et al. (2013) pointed out that a green building should have a good demand and economic values as well as socio-cultural values; it should be pleasing aesthetically with minimum negative impact on the environment. A sustainable building should be designed and constructed to continue and to be operated and maintained over decades. Finally, at the end of that long period it should be demolished without adversely affecting or polluting the natural environment. The whole lifecycle of a building should be well considered; a building that is adaptable to the changing requirements of performance and functionality. The materials used in such buildings should be reused or given back to the nature (Straube, 2006).

In fact, these needs are different parameters to be considered when accessing sustainable buildings (Lowe, 2007), which are difficult to identify via energy use simulation. There are discrepancies between the actual and as-designed energy use: it is difficult to identify environmental uncertainties, design mistakes or the influences of occupant behaviour and actions through the process of simulation, as it is well known, people's behaviour and need are not easily predictable (Yu et al., 2011). All the stakeholders should know the needs of the occupants beforehand, to design a building that will meet those needs (Berardi, 2013; UNAC, 2002).

2.2 THE PERFORMANCE GAP

The discrepancies between actual and as-designed energy consumption is known as the 'energy performance gap'. These performance gaps have been identified by several researchers (Sunikka-Blank & Galvin, 2012; Menezes et al. 2012). Renovated buildings can, on paper, achieve similar energy performances to new buildings, but these are not achieved in practice (Brom et al., 2018). Building energy performance is regulated, which has positive effect on both the environment and the construction industry; also new buildings are designed to be more energy efficient than older ones. However, these increased efficiencies have not been sufficient in prohibiting building energy consumption. Several studies have revealed that there are differences between the predicted and actual energy performance of a building during operation and occupancy phases (Bordass et al., 2001).

Studies (Norford et al., 1994; Pegg et al., 2007) confirm that buildings practically can use twice the amount of their theoretical predicted energy performance.

2.2.1 UNDERLYING CAUSES FOR THE PERFORMANCE GAP

- Complexity of design: this complexity can introduce problems during building construction, which, clearly affects building performance (Dronkelaar et al., 2016). Simplicity must be the main aim of the design as many of the underlying issues are related to the complexity of the building.
- Uncertainty in building energy modelling: in the detailed design stage, building energy modelling requires a high level of detail in order to predict energy use of a building. Other uncertainties are less understood to be established in modelling procedures. Better understanding toward well-defined assumptions can assist in a more accurately and confidently predicted performance of a building (Heidarinejad et al., 2013). Energy use simulation using different tools and models, developed for different reasons and as such introduce variability in the results when modelling the same building. These tools are utilized for the purpose of building performance prediction but still they do not give credible and relatively accurate results (Dronkelaar et al., 2016).
- Environmental uncertainties: uncertainties are mainly divided into two groups; one considering the uncertainty due to climate change and the other concerning uncertainties due to the use of synthetic weather data files (Wang et al., 2012).
- Changes after design: during building design and construction, often products or changes are value engineered, affecting building performance, while not being fed back to the design team for evaluation against the required performance standard. Morant (2012) reported inconsistencies between design specification and installed lighting loads in an office, which had a considerable impact on the discrepancy between predicted and actual measured electricity consumption.

- Quality of building elements & workmanship: differences exist between the building design and the actual constructed buildings. As building regulations become more stringent and new technologies are introduced, the quality of construction must be improved. On-site workmanship needs to adapt and be trained to these increasing levels of complexity in building construction. These issues are more prone to affect the energy performance in residential buildings, where usually the performance of the thermal envelope is more important.
- Poor commissioning: when a building construction is completed, it is handed over, if the installation and commissioning of building services will be done poorly, it can result in reduced system efficiency and compromising the air tightness and ventilation strategies. Pang et al. (2012) reported poor commissioning of control measures and therefore they were not set up for good control, and operation.
- Occupant behaviour: human have a substantial influence on the energy performance of a building by handling controls, such as lighting, sun shading, doors, windows openings, set-points, use of appliances and mainly through their presence. People are very different in their behavior which, makes their influence on energy consumption highly unexpected and variable. Parys et al. (2010) reported a SD of up to 10% on energy use to be related to occupant behavior.

Although occupant behaviour is considered as the main discussions for the energy performance gap, other issues should also be considered. “Possible explanations for reasons behind energy performance gap are: i) construction mistakes, ii) improper adjustment of equipment, and iii) excessive simplification in simulation models” (Brom et al., 2018).

Interestingly Menezes et al. (2012) conducted a study in which the occupants of non-green buildings consumed less gas than what was expected, while occupants of green buildings consumed more than what was expected.

The building occupants have great influence on residential energy consumption” (Gram-Hanssen, 2017). Some researchers claim that the performance gap is mainly caused by occupant behaviour (Gram-Hanssen & Georg, 2018). Researchers have tried to address occupant behaviour to address some of the issues with regards to performance variations. Several governmental authorities have run campaigns to change occupant environmental behaviours, as it is necessary to understand how occupants consume energy in order to come up with a more effective energy conservation campaigns to help policy-makers and authorities to reduce the energy-related performance gap. Governmental authorities in different parts of the world strengthen the building codes and regulations to favour green certification and to understand how the occupant behaviour are related to the social environment and the society of which they are a part (Ciddel, 2009).

The performance gap has been considered in several countries (Gram-Hanssen et al., 2017). Still the lack of available data related to occupant environmental behaviour is potentially one of the reasons researchers found limited evidence for the negative impact of occupant behaviour on the building energy consumption. Occupants assess various aspects of their building usefulness and impacts, however, very few occupants are aware of energy saving measures (Wood & Newborough, 2003) and technological efficiency as well as the building's capabilities. Therefore, they do not behave in an environmentally-friendly way which would impact positively on performance gap reduction.

Some studies mention that there is an emerging trend of a special type of smart home, with technological systems to help occupants to reduce their energy consumption through monitoring and control devices (Darby, 2018); but occupant preferences regarding their accommodation continue to differ. Other than technological efficiency there are many things that can influence building performance, such as: i) comfort norms, ii) gender issues, iii) time constraints, and iv) personal preferences (Gram-Hanssen and Georg, 2018). Many researchers, policy makers and green agencies mistakenly focus on occupant characteristics instead of real occupant environmental behaviour. The priority focus should be to study the possible impact of occupant environmental behaviour on building performance in order to improve the energy use performance of green buildings, as "it is people who use energy, not the buildings" (Janda, 2011).

2.2.2 SOFT LANDINGS

Soft Landings is about narrowing the performance gap between design and operational outcomes. It is a building delivery process that can run throughout the project lifecycle from inception to completion and even during operation (BSRIA, 2019). Soft Landings is a process that helps to produce a building that delivers the operational goals that were set for it at the inception of the design and project delivery. To paraphrase, it helps make the building do what it says on the tin. It is troubleshooting the building after operation to bring the performance of the building to the desired level as per design.

Based on BSRIA, Soft Landings approach is gaining momentum as a process to meet 21st century construction projects requirement by:

- Being increasingly specified by clients,
- Providing a means of earning credits in BREEAM for New Construction,
- Being in the process of adoption for governmental procurement policy,
- Assisting project teams to deliver lower carbon buildings within constrained budgets.

Treating Soft Landings as just another contractual deliverable is not necessarily in the client's interest. For a start, the lead contractor might capture most if not all Soft Landings activities for itself as the single point of delivery agent, and not involving the architects and engineers. There's also a strong chance that Soft Landings activities might be simply sub-contracted down the chain rather than be carefully considered. In this process the project team need to be engaged. In any way involvement of project team and industry professionals throughout this process can help to reduce performance gap by finding why and where the system doesn't work properly and resolve those issues. Even more recently Soft Landings has become a recognized credit on BREEAM 2011 (BSRIA, 2019). One of the important reasons behind performance gap which is occupant behaviour can be monitored and addressed during Soft Landings process.

2.3 ENVIRONMENTAL EVALUATION TOOLS AND SYSTEMS

In this section, there is an introduction to some tools and systems that were implemented to reduce the energy performance gaps; particularly initiatives focused on environmental issues, design mistakes and occupant behaviour. Characteristics of green buildings are identified by green building rating systems to introduce building codes to improve market penetration (Todd et al., 2013).

Building performance as well as sustainability is now a major concern of construction industry professionals (Ding, 2008; Doan et al., 2017) and environmental building performance assessment is one of the major issues within sustainable building industry (Cole, 1998; Cooper, 1999; Holmes & Hudson, 2000).

Building designers and construction professionals as well as building occupants have been concerned with building performance since long time ago (Cooper, 1999). Considerable amount of effort has been put into advancing systems to measure and monitor a building's performance over its lifecycle. Advancement of such systems are important to evaluate how successful a project is with regards to balancing issues associated with energy and environment, while considering both the social and technological aspects of a project (Clements-Croome, 2004).

Operational techniques are maintained by models and software which are known as 'environmental evaluation tools' (Papadopoulos & Giama, 2009). They are used to deal with the following issues:

- Life cycle assessment (LCA),
- Material flow accounting (MFA),
- Life cycle costing (LCC),
- Environment risk assessment (ERA),
- Environmental performance evaluation (EPE),
- Total quality environmental management (TQEM)
- Total cost accounting (TCA),
- Environmental management systems (EMS), and
- Rating systems (Papadopoulos & Giama, 2009).

These tools can be used to evaluate a building's performance and energy consumption, as well as to fulfill the requirement of the long-term objective which is to ensure sustainable economic growth. The specific assessment tools requirements are different in terms of which environmental aspects are included and how indicators are interpreted (Ding, 2008). Most of the environmental evaluation tools are based on some form of life-cycle assessment database (Seo et al., 2006). Tools are mainly in two categories: i) assessment tools which provide quantitative performance indicators for design alternatives, and ii) rating tools which determine the performance level of a building ranked in the number of stars awarded.

Building environmental assessment tools vary excessively. The tools have been developed for different needs and purposes to assess buildings such as: a) residential buildings, b) commercial buildings, and c) many other types of buildings. Some of the tools are appropriate for assessing the whole building range, while some of the tools can only be used for assessing new buildings or office buildings. The tools cover the life cycle of a building in different ways, informed by different guidelines and databases. Moreover, different cultural factors and various regulations in different countries complicate the green building situation even further. The comparison between the tools and their results is difficult, if not impossible. The use of the tools mentioned is neither simple nor obvious.

Decisions need to be made regarding: i) where and when they should be used, ii) who should use them, and iii) how the results from the assessment should be employed (Haapio & Viitaniemi, 2008). Most probably, these issues have reduced the use and utilisation of building environmental assessment tools and methods. Should that be the case there is a requirement for further communication, interaction, and recognition between members of the design team, industry professionals, energy authorities, policy makers, building operators and building occupants. Although green building assessment tools and rating systems have been the main concern for various researchers during the past 20 years, there is still no systematic review of the detailed criteria and updates regarding current assessment tools and green rating systems (Haapio & Viitaniemi, 2008; Ding, 2008; Doan et al., 2017).

2.4 GREEN BUILDING RATING SYSTEMS

Various green rating systems exist worldwide to evaluate the sustainability of construction projects. Their categories and criteria have been updated continuously to follow the trend of sustainable developments (Doan et al., 2017).

Rating systems are the most used environmental evaluation methods. They are used for construction industry targeting sustainability. According to Papadopoulos & Giama (2009) green rating systems often use methods like other evaluation tools. Designers use these tools to adjust their design to the environmental standards (Fernandez-Solis et al., 2011). Government-initiated task forces developed green building rating systems to address issues related to the increasing energy consumption worldwide and wastage awareness. The designers who are grounded to the construction industry created such systems with an understanding of the local environment, regional conditions, climate, and culture (Cole & Valdebenito, 2013). Many countries began to adopt necessary green approaches for their construction developments and that was when green rating systems became enunciated.

Some of the widely used rating systems are Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Methodology (BREEAM), and Green Globe, Canada (Papadopoulos & Giama, 2009).

Some other rating systems are Green Star, Green Building Council of Australia (GBCA), Building Environmental Performance Assessment Criteria (BEPAC) in Canada, and Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) in Japan (Ding, 2008; Ghaffarianhoseini et al., 2013).

The concentration in this research is on the LEED initiative that was developed by the U.S. green building council. LEED includes evaluation characteristics which aims at being user-friendly. It is one of the most recognised rating systems used in Dubai-UAE, based on credits achieved, as it is a system which is intended to help building operators to be environmentally responsible. From 1994 to 2006, LEED grew from specifying just one standard to a very comprehensive system covering all aspects of the construction process (USGBC, 2012). LEED evaluates environmental factors including quality categories and it was updated in 2017, a move which indicates it is putting efforts to revise and update their criteria more frequently, in order to monitor and guide the rapid development within construction industry sustainability approaches (Doan et al., 2017).

BREEAM is the first established rating system of its kind; having been created in 1988 at the Building Research Establishment (BRE), which is based in Watford, England, UK. The first version was introduced in the early 1990s. Based on the 1996 CSA publication of BREEAM Canada, Green Globes for existing buildings was developed in 2000 as the first online energy conservation system. In BREEAM 2018, there is POEs which is seen as a systematic way of providing feedback during a building's lifecycle and is designed to identify and find solutions to problems in buildings and to respond to occupant needs. POEs through environmental monitoring systems provide physical measurement data on a building's performance. This approach compares the actual performance with both the initial design intention as well as health-related and environmental standards (BREEAM, 2018; Doan et al, 2017).

It should be noted that UK's BREEAM is the only tool which could assess all sustainable factors under management category (Doan et al., 2017).

According to the BRE group (2018), BREEAM Post Occupancy Evaluation (POE) environmental monitoring systems are designed to:

- Show if the original building environmental design specifications have been delivered in practice.
- Demonstrate compliance with relevant health-related and environmental standards.
- Highlight problems with the building operation that can be addressed and solved.
- Provide knowledge and examples that can be used to improve design and procurement on future projects.
- Act as a benchmarking aid to compare:
    - The performance between different types of buildings, ventilation systems, building operation and management.
    - The performance of the building over time.

Unfortunately, there is no such inclusion of occupant behaviour in the comprehensive evaluation technique during the occupancy phase in LEED green certification, while POE should be a crucial part of each rating system.

GBCA is been recognised as the sustainability rating system worldwide. There are four Green Star rating systems available for certification which are: i) Communities, ii) Design & as Built, iii) Interiors and iv) Performance.

BEPAC is the first comprehensive method in Canada to assess the environmental performance of new and existing commercial buildings. BEPAC consists of some environmental criteria, in five major topics: i) ozone layer protection, ii) environmental impacts of energy use, iii) indoor environmental quality, iv) resource conservation, and v) site and transportation.

CASBEE is the green building assessment system in Japan. CASBEE was developed by a research committee established in 2001 to evaluate the energy performance of buildings and the built environment. It aims at enhancing the quality of occupant life and to decrease the resource use and environmental loads. There are different scales of CASBEE systems such as for housing, building, urban and city.

All of the above-mentioned green building rating systems and guidelines aim to standardise sustainability in the built environment; however, each of them has adopted their own methodologies for designing and constructing interiors, buildings and neighbourhoods having been influenced by their unique needs, cultures and physical conditions.

2.4.1 THE LEED RATING SYSTEM

The LEED rating system is being widely used in the United Arab Emirates (UAE) and other countries worldwide (Ciddel, 2009). LEED is a voluntary standard which was developed by the US Green Building Council (USGBC) and was first launched in 1998, with a pilot version (LEED 1.0). Although it was released after BREEAM, it is considered as the most widely adopted rating system based on the number of countries that have adopted it. There were over 79,000 LEED projects across 135 countries in 2012; LEED had reached nearly 150 countries and territories in 2014, and over 160 countries and territories in 2017 (Doan et al., 2017).

According to USGBC, LEED was mainly introduced only to raise energy awareness (Behbehani, 2012). It has gained satisfactory credibility among construction professionals in many different parts of the world since 1998 (Fernandez-Solis et al., 2011). That success was due to its positive influence on the design, construction, and operation of buildings (Todd et al., 2013).

The LEED green building rating system has gone through many changes. It started with LEED for new construction and major renovations (NC), LEED for existing buildings (EB), LEED for commercial interiors (CI), and LEED for cores and shells (CS). Later LEED has expanded to include LEED for homes, LEED for neighbourhood development, LEED for schools, LEED for retail, and LEED for healthcare. Out of a total of 110 points for the new construction (NC) and the major renovation (MR), a residential building must have 40-49 points for a general LEED certification, 50-59 points for silver, 60-79 points for gold and 80-110 for platinum certification (Reposa, 2009; USGBC, 2012). It is interesting to note that platinum rated projects are usually owned by non-profit organisations (Todd et al., 2013).

LEED professionals and design teams should start with green approaches from the design phase all way to the operation and post-occupancy phase. This requirement is suggested because studies have demonstrated that operating costs are lower if there will be involvement of professionals, operators, and occupants during occupancy phase (Matthiessen & Morris, 2007).

LEED Categories

In brief, the LEED-NC consists of eight categories: i) location and transportation ii) sustainable sites, iii) water efficiency, iv) energy and atmosphere, v) materials and resources, and vi) indoor environmental quality, vii) innovation, and viii) regional priority (Reposa, 2009; USGBC, 2012).

1. **Location and transportation** category rewards thoughtful decision on the project's location and its connection / access to public transport, restaurants, parks, etc. This category also encourages bicycling and associated improvements in public health by setting requirements for bicycle facilities, as well as focusing on transportation efficiency.
2. **Sustainable sites** category includes site selection, development density, environmental surrounding, and landscaping. The category focuses on strategies that reduce the impact on the ecosystem as well as integrating the site with local ecosystems, water resources, site development and preserving biodiversity that natural systems rely on.
3. **Water efficiency** category includes wastewater management in a focus towards water conservation. This category focuses on potable water usage and initiating innovative wastewater treatment techniques. Treating wastewater is an excellent example to reduce overall consumption.
4. **Energy and atmosphere** category addresses improving energy efficiency and renewable energy. It encourages better building energy performance through innovative approaches.
5. **Material and resources** category concentrates on reducing the embodied energy and other effects associated with the extraction, consumption, and disposal of building materials. It includes building construction waste management, reuse of materials, recycled contents, and regional materials. This category encourages using sustainable building materials and reducing construction waste, as well as the efficient management and use of renewable resources.

6. **Indoor environmental quality** category focuses on, and rewards, decisions made by project teams about indoor air quality. The category involves ventilation, low VOC levels (volatile organic compounds) in materials, indoor chemical and pollutant source control, controllability of systems, day lighting and views. It improves a building's value and enhances productivity by increasing the quality of indoor environment and controllability of visual, thermal, and acoustic comfort.
7. **Design & innovation** category includes exemplary performance related to existing LEED credits and innovative performance. Sustainable design strategies are continually improving. New technologies and up-to-date scientific research influences building design. This category needs involvement of a LEED accredited professional from the design phase (Ciddel, 2009). The purpose of this category is to recognise innovative building design and features.
8. **Regional priority** category has been designed as particularly important aspects for specific regions. In LEED 2009, the USGBC introduced the concept of regional priority to adapt LEED to suit the local conditions found in foreign countries (Pushkar, 2018). This category encourages project team to concentrate on their local environmental priorities.

LEED categories and credits are frequently updated. Currently the LEED committee considers the introduction of environment and people wellbeing within a specific building (Horst & Todd, 2008). This will help the green building occupants to become aware of their environmental behaviour outcome. However, some critics suggest that LEED is not being sufficiently sensitive.

The category of the points is shown in the project checklist presented in Table 2.1. Under each category there are some prerequisites that need to be addressed and then there are credits that can add points. For example, the sustainable sites category, the *'construction activity pollution prevention'* is a prerequisite and required for the building. However, other credits such as: a) site assessment (1point), b) site development ; protect or restore habitat (up to 2 points), c) open space (1 point), d) rainwater management (up to 3 points), e) heat island reduction (up to 2 points) and f) light pollution reduction (1 point) can add points in order to access to a higher level of building certification possible points of 110.

Table 2. 1 LEED v4, Project checklist for points

LEED v4 for BD+C: New Construction and Major Renovation
Project Checklist

Project Name:
Date:

Y	?	N			
			Credit	Integrative Process	1
0	**0**	**0**	**Location and Transportation**		**16**
			Credit	LEED for Neighborhood Development Location	16
			Credit	Sensitive Land Protection	1
			Credit	High Priority Site	2
			Credit	Surrounding Density and Diverse Uses	5
			Credit	Access to Quality Transit	5
			Credit	Bicycle Facilities	1
			Credit	Reduced Parking Footprint	1
			Credit	Green Vehicles	1
0	**0**	**0**	**Sustainable Sites**		**10**
Y			Prereq	Construction Activity Pollution Prevention	Required
			Credit	Site Assessment	1
			Credit	Site Development - Protect or Restore Habitat	2
			Credit	Open Space	1
			Credit	Rainwater Management	3
			Credit	Heat Island Reduction	2
			Credit	Light Pollution Reduction	1
0	**0**	**0**	**Water Efficiency**		**11**
Y			Prereq	Outdoor Water Use Reduction	Required
Y			Prereq	Indoor Water Use Reduction	Required
Y			Prereq	Building-Level Water Metering	Required
			Credit	Outdoor Water Use Reduction	2
			Credit	Indoor Water Use Reduction	6
			Credit	Cooling Tower Water Use	2
			Credit	Water Metering	1
0	**0**	**0**	**Energy and Atmosphere**		**33**
Y			Prereq	Fundamental Commissioning and Verification	Required
Y			Prereq	Minimum Energy Performance	Required
Y			Prereq	Building-Level Energy Metering	Required
Y			Prereq	Fundamental Refrigerant Management	Required
			Credit	Enhanced Commissioning	6
			Credit	Optimize Energy Performance	18
			Credit	Advanced Energy Metering	1
			Credit	Demand Response	2
			Credit	Renewable Energy Production	3
			Credit	Enhanced Refrigerant Management	1
			Credit	Green Power and Carbon Offsets	2
0	**0**	**0**	**Materials and Resources**		**13**
Y			Prereq	Storage and Collection of Recyclables	Required
Y			Prereq	Construction and Demolition Waste Management Planning	Required
			Credit	Building Life-Cycle Impact Reduction	5
			Credit	Building Product Disclosure and Optimization - Environmental Product Declarations	2
			Credit	Building Product Disclosure and Optimization - Sourcing of Raw Materials	2
			Credit	Building Product Disclosure and Optimization - Material Ingredients	2
			Credit	Construction and Demolition Waste Management	2
0	**0**	**0**	**Indoor Environmental Quality**		**16**
Y			Prereq	Minimum Indoor Air Quality Performance	Required
Y			Prereq	Environmental Tobacco Smoke Control	Required
			Credit	Enhanced Indoor Air Quality Strategies	2
			Credit	Low-Emitting Materials	3
			Credit	Construction Indoor Air Quality Management Plan	1
			Credit	Indoor Air Quality Assessment	2
			Credit	Thermal Comfort	1
			Credit	Interior Lighting	2
			Credit	Daylight	3
			Credit	Quality Views	1
			Credit	Acoustic Performance	1
0	**0**	**0**	**Innovation**		**6**
			Credit	Innovation	5
			Credit	LEED Accredited Professional	1
0	**0**	**0**	**Regional Priority**		**4**
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
0	**0**	**0**	**TOTALS**	**Possible Points:**	**110**

Certified: 40 to 49 points, **Silver:** 50 to 59 points, **Gold:** 60 to 79 points, **Platinum:** 80 to 110

2.4.2 LEED AND ITS IMPACT ON BUILDING CODE DEVELOPMENT

Governments worldwide rely on building codes in order to improve sustainability and to address important issues including public health and safety. These codes are mainly to protect people from harm caused by structural collapse, fire, and other building related hazards. Sustainability, the key principle underlying green building, is a global trend that influences occupant behaviours and business decisions across a wide range of industries (Runde & Thoyre, 2010; Nicholl & Hall, 2007).

In a large part, building codes establish a building's safety, quality, energy-related and environmental performance. Buildings can be retrofitted, but still many aspects of a building's systems are designed and installed at the early stage of the project and therefore they can be too costly and hard to be changed. Building codes, together with design and construction decisions, influence our life, health and comfort every day. Some needs such as the quality of lighting, acoustics, and the air we breathe have major effects on our productivity and well-being, as we spend nearly 90 percent of our time inside buildings (U.S. Environmental Protection Agency, EPA).

The major effect of the U.S. Green Building Council (USGBC) and LEED have increased the need for building codes to address the issues with regards to understanding of building-related hazards.

The USGBC addressed a broad vision of hazards to occupants and environmental health within the building codes. USGBC established a standardised rating system mainly focusing on the energy performance of building projects. The LEED are the developed systems to evaluate the environmental and energy performance of the buildings. From the efficiency of water and energy consumption to location, the effects of materials consumed, LEED is designed and developed to recognise buildings that go beyond minimum code adoption (USGBC, 2012).

Soon after its inception, LEED has become an acceptable industry practice and professionals recognized the need for building codes. These quantitative measures were suitable and appropriate for higher adoption and application of green practices by building departments and regulatory authorities.

LEED was designed as a rating system and is not considered as codes or as a rigid standard. It became clear that all aspects of sustainability such as: i) social, ii) environmental, and iii) economic conditions found the necessity for reviewing codes and standards with regards to building safety. USGBC also collaborated with a building safety expert's network in order to identify barriers, exchange best practices, lead discussions on enforcement and compliance with green building programmes, as well as providing information and education (USGBC, 2012).

2.4.3 DRAWBACKS OF LEED

LEED's rating categories generally encourage sustainable design, health, and economic benefits; however, they do not consider the significance of the human dimensions (Behbehani, 2012). The LEED rating systems and certification have been the target of much criticism in recent years. According to Schendler and Udall (2005) there are problems associated with LEED rating systems.

Recently the latest LEED for homes included an awareness and education category. According to USGBC website, this category motivates designers, constructors and policy makers to provide occupants and building managers with the training and tools that they need to make their home green and to learn how to get the most of those technology-oriented systems (USGBC, 2012). LEED introduced knowledge and education as one of its benchmarks where occupant education and training on how to operate and maintain the building is the key focus (Reposa, 2009). However, it does not take into consideration the occupant capabilities, attitudes and behaviour. Jones and Vyas (2008) mentioned "measuring or verifying post-occupancy performance of homes will help in increasing the data for analysing and improving on the real performance attributes of green residential buildings".

Post Occupancy Evaluation (POE) started in the 1960s. Meir et al. (2009) explained the benefits of POE which consists of three categories: i) short-term benefits include obtaining occupant feedback on problems in buildings and the identification of solutions; ii) the medium-term benefits include feedback of the positive and negative lessons learned that can be fed into the next building cycle; and iii) the long-term benefits aim at the creation of databases and the update, upgrade and generation of planning and design protocols (Meir et al., 2009). Scholarly research exploring the performance of LEED-certified buildings has focused mostly on Post Occupancy Evaluations (POEs) of energy performances, indoor environmental qualities, day lighting, health-related issues, and occupant satisfaction. However, there are very few studies exploring the environmental knowledge, attitudes and behaviour of the occupants within LEED-certified buildings (Behbehani, 2012).

The behaviour and social being of building occupants were the least researched topics (Berardi, 2013). Berardi (2013) also stated that the social and psychological aspects of a sustainable building can influence the social norms of building occupants. Jones & Vyas, (2008) stated that LEED is not designed in a way to deeply understand occupant behaviour during post-occupancy phase. It has been also revealed that LEED has no inclusion of environmental occupant behaviour.

The focus in new construction manuals should be environmental issues. Society should also emphasize in neighbourhood development manuals in order to better educate people.

Recently, the ability of the occupants to maintain and operate fully equipped residential buildings is not considered. Further, there is effective feedback as to how occupant environmental behaviour can be influenced. Such manipulation can encourage occupants to better make use of the local facilities. LEED also lacks inclusion of occupant behaviour in terms of collecting data to know their level of awareness and requirements for their education (Papadopoulos & Giama, 2009) to minimise the environmental and energy performance gap.

2.5 BUILDING OCCUPANT BEHAVIOUR

People behave unpredictably. Human behaviour consists of numerous aspects, which are not in conjunction with, or do not complement, the concept of sustainability (Humber et al., 2009). Occupant behaviour is complex and requires an interdisciplinary approach to be better understood. On the one hand, occupant environmental behaviour is influenced by external factors such as economy, climate, and culture, and at the same time by internal factors such as comfort preference, the individual’s psychology and their physiology (Yan & Hong, 2018).

A stochastic approach towards modelling occupant environmental behaviour became popular, in contrast to the static description of occupant behaviour based on assumptions made, this new approach accounts for the fact that occupants do not always make logical selection therefore, they are acting stochastically rather than deterministically (Gunay et al., 2013). Existing monitoring studies of drivers, needs, actions and systems, behavioural models, and simulation studies, have captured the principal aspects of environmental human behaviour within a building (Turner et al., 2013). Social norms, attitude and income are considered as the main determinants of occupant environmental behaviour (Marcellafield, 2007).

Figure 2.1 showed that sustainability consists of three important aspects: ecological, economic, and social conditions. Economic and ecological aspects are incorporated with 'social' being. The most important aspect of sustainability relates to the occupant energy consumption (Berardi, 2013). It is reasonable to suggest that there is a high level of general negligence as the issue of social considerations is only rarely raised when energy consumption is being discussed.

Figure 2. 2 Priorities Pyramid (Fischer et al., 2012)

Figure 2.2 shows that changes for sustainable construction through policy actions and management can be made easier at the top of the pyramid. At the base of the pyramid, it seems to be more complicated to make any changes as it gets slower and more difficult to influence people social norms and beliefs (Fischer et al., 2012).

The factors which affect the environmental behaviour of occupants are categorized as follow:

- Climate conditions,

- Building size, location, etc.,
- Occupant beliefs and attitude,
- Building operation and systems,
- Economic factors such as the cost of energy bills,
- Social factors such as level of awareness and education, and
- Quality of indoor environment (Yu et al., 2011).

The behaviour of occupants might change if there are cost-effective approaches towards reducing energy consumption (Chen et al., 2012). Kaiser et al. (1999) mentioned that occupants might have positive attitude towards environmental sustainability, but they might not behave environmentally-friendly due to the fact that there were not enough motivations such as economic concerns, cash incentives, etc.

Barthelmes et al. (2016) believe that occupant behaviour was classified into three lifestyles such as low consumers, standard consumers and high consumers based on their needs and preferences.

Yun et al. (2009) reviewed occupant behaviour that had impact on thermal performance of a naturally ventilated building in summer. They developed a probabilistic occupant behaviour algorithm classifying occupant behaviour as active, medium, and passive while they were opening window, etc. They could indicate that occupant behaviour had significant impact on thermal performance.

Hong et al. (2013) classified three types of occupant behaviour such as austerity, standard and wasteful modelling with Energy Plus, concluding that the austerity type could improve the energy savings by 50%.

2.5.1 OCCUPANT BEHAVIOUR AFFECTING BUILDING PERFORMANCE

Occupant behaviour can be defined as people's actions in certain ways while their actions might have impact on the environment and a building's environmental and energy performance (Hoes et al., 2009). The researchers found that occupant behaviour is an important influence on the building's energy performance. Some behaviours could spread throughout the entire building, for example, if one occupant recognises that their energy consumption is more than the neighbours, then they can be motivated to improve their environmental behaviour (Nolan et al. 2008).

Brandemuehl & Field, (2011) found that the main influencing factor was the occupant need towards achieving their comfort levels. In order to promote sustainable development within construction industry, occupant behaviour needs to be pushed towards saving energy (Hong et al., 2015).

In recent years, scholars and policy makers have emphasised the significance of not only the built environment but also occupant behaviours on the depletion of natural resources in terms of both quantity and quality. One response to this unsatisfactory situation is to call for the diffusion of environmentally-friendly behaviours, such as recycling and the use of sustainable modes of travel (Stern et al., 1994; Stern, 2000). Gibson et al. (2010) argue that occupants are understood primarily as sites of consumption, rather than of production. Hurth (2010) explains that the increased importance and incidence of consumption, especially in affluent households, is due to: a) existing social structures, b) an increase in consumption choices, c) existing marketing and advertising strategies, and d) increased disposable incomes.

2.5.2 APPROACHES TOWARDS ENVIRONMENTALLY-FRIENDLY BEHAVIOUR

Occupants are usually not aware of the outcome of their certain environmental behaviour. With such a billing model without detailed information, occupants are completely unaware of their day-to-day energy usage, unless they are dedicated meter checkers (Humber et al., 2009). Therefore, awareness and knowledge need to be created if those occupants are to reduce their energy consumption. Gann (2003) argues that the two terms, ‘information’ and ‘knowledge’, are not interchangeable while knowledge signifies a deeper understanding of a subject and enables the individual to feel capable of forming judgments, making interpretations, and having understanding. Knowledge is also typically accumulated through education and experience. Information, on the other hand, is data which can be stored and distributed, and therefore by itself does not provide any significance or deep understanding.

Studies conducted by Chen et al. (2012) showed that influencing occupant behaviour through the provision of energy use information could result in a reduction of 8% in U.S. energy consumption (Chen et al., 2012). There are following methods to decrease energy consumption:

- Constructing low energy buildings,
- Using low energy equipment, and
- Promoting energy conscious behaviour among a building's occupants (Wood & Newborough, 2003).

General information in the form of manuals and/or workshops do not change the environmental behaviour of the occupants while feedback approaches such as smart self-monitoring system is more likely to change such behaviour (Humber et al., 2009).

Nair (2012) reported that Cialdini, (2007) found about *'six weapons of influence'* that can be applied to change occupant behaviour such as: i) authority, ii) social proof, iii) liking, iv) scarcity, v) commitment and vi) reciprocation.

Other methods of effective feedback mentioned by Lockton et al. (2008) are:

- Self-monitoring,
- Customising occupant behaviour,
- Analysing the occupant behaviour by other occupants,
- Reinforcing the process, and
- Simplifying a procedure.

Feedback is the key to reduce energy consumption as it gives the consumer a clear indication of how efficient they are, or are not, towards saving their energy (Lockton et al., 2008). Nair (2012) reported that in a study conducted by Winett and Neale (1979), small stickers were put on the apartment door for those occupants who left their lights on when they were not using them, these stickers had no serious impact on the behaviour of occupants while they still left their lights on, so the researchers left bigger stickers that were easily visible to the neighbours on the doors of occupants who left their lights on, it was interestingly found that bigger stickers prompted a 40% reduction in energy usage by the stickered occupants (Winett & Neale, 1979).

Ouyang & Hokao, (2009) conducted a study on the occupants of two identical buildings. Occupants of building A were educated to behave environmentally-friendly, while those in building B were required to keep their behaviour unchanged. It was found that the building A occupants reduced their electricity consumption by more than 10%. Therefore, education and training play an important role in reducing energy consumption.

Financial incentive can also encourage occupants to reduce energy consumption. Rewards and incentives have been frequently used to motivate and sustain behavioral change. McKenzie-Mohr and Smith (1999) sent a pamphlet on energy conservation to two occupant groups. One group in their study received a shower flow restrictor together with the pamphlet while the other group received just the pamphlet. Occupants who received the shower flow restrictor were more likely to engage in the other conservation actions mentioned in the pamphlet (e.g., reducing the temperature on their hot water heaters, installing setback thermostats, and cleaning their furnaces). Pink (2010) and Ariely (2009), describe situations in which people will be motivated to work hard without monetary compensation because of friendship ties, the ability to be creative, or their belief in a larger cause and therefore, monetary awards are not necessarily the only motivating factor and creating socio-cultural environment is crucial to motivate occupants effectively.

Post Occupancy Evaluations (POEs) is a method by which an occupant evaluates responses and supplies information via a questionnaire. The existing POEs mainly focus on occupant environmental behaviour, comfort and satisfaction. Researchers noted that receiving appropriate feedback from occupants through POEs is an effective way of ensuring whether occupants behave in an environmentally-friendly manner (Wood & Newborough, 2003).

Changes in occupant behaviour can be achieved by addressing everyone’s energy consumption awareness, as well as facilitating the occupant group’s knowledge and perceptions through advertising, marketing, and other information strategies (Vlek & Steg, 2007). A financial refund can be made to the occupants who save energy as their reward (Winett & Neale, 1979).

Research projects can be undertaken by professionals to gather information about occupant energy usage which, requires the consent of occupants, as it may be considered as an intrusion into their personal privacy (Marcellafield, 2007). Chen et al. (2012) mentioned that in future research studies, occupant environmental behaviour must be reviewed and analysed, as the existing POE is not enough.

2.6 HUMAN BEHAVIOUR MODELS AND FRAMEWORKS

Technology-oriented systems and building design measures recommended by green agencies are designed to affect building occupant behaviours. To achieve the potential energy savings of green buildings, there is a requirement for a change in their occupant environmental behaviour. Since building occupants behave stochastically, the interplay between humans, buildings, and the environment is extremely complex. Over the past 40 years, several models and frameworks describing energy-centric human behaviour have been proposed by various researchers (Fishbein & Ajzen, 1975 & 2010; Ajzen, 1991; Turner & Hong, 2013; Hong et al.2015; Groot-Marcus et al., 2006; Van Raaij & Verhallen, 1983). These models and frameworks consider occupants as reactive agents within a contextual environment, rather than passive receptors. Occupants-focused environmental models and frameworks try to capture the unpredictable human cognition process by explaining the bond between the human's *'inside world'* inputs (drivers and needs) and the environment which is the source of *'outside world'* outputs (Hong et al., 2015). The models and frameworks which are related to this study are discussed below.

2.6.1 THE REASONED ACTION MODEL

Figure 2.3 illustrates the theory of reasoned action (Ajzen & Fishbein, 1980) which offers a model that can predict the reason behind a behaviour based on a human's attitudinal and normative beliefs. This model was developed to include the variables such as: attitude, perceived behavioural control, normative beliefs, intention and finally behaviour. The final model was then renamed *'the theory of planned behaviour'* (Ajzen, 1991). These models have been used to review and assess occupant behaviours, but still there is an argument that they are not appropriate to be used in evaluating the multi-individuals and multi-departmental nature of the decision-making processes existing in a complex occupants-energy system (Thompson & Panayiotopoulos, 1999).

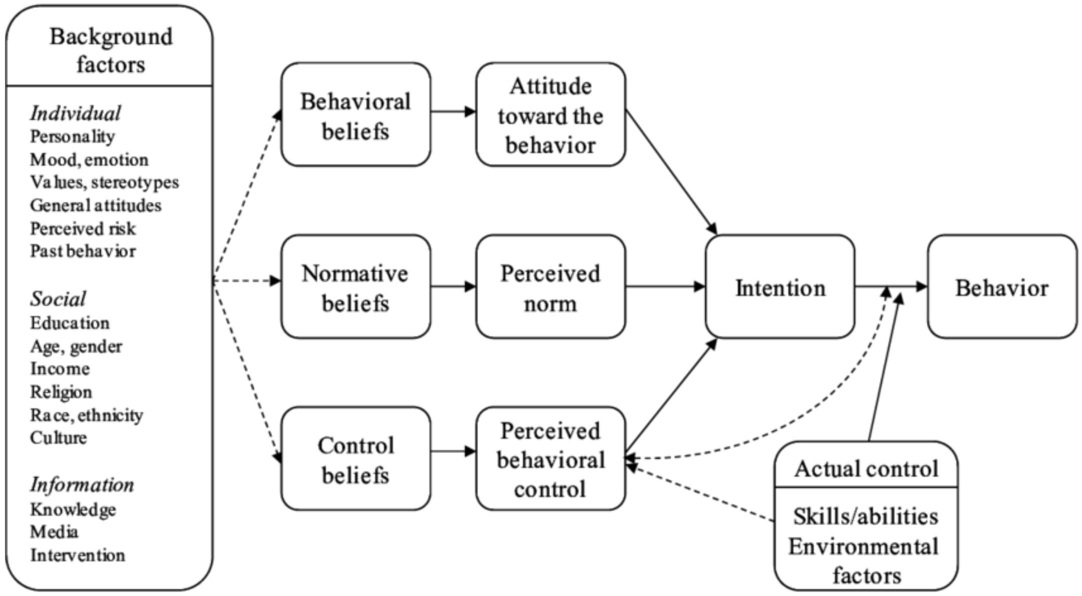

Figure 2. 3 Theory of Reasoned Action (Fishbein & Ajzen, 1975, revised 2010)

Fishbein and Ajzen's model (Figure 2.3) assumes that human is essentially rational when they behave in certain ways, their assumption has been seriously challenged by behavioural economists over the last few decades. Occupant backgrounds might also have indirect impacts on their engagement in some certain environmentally-friendly behaviours. As a result, occupant environmental behaviours might not always be performed predictably and might be very circumstantial in some cases. Fishbein and Ajzen (1975) supported a perspective on the determinants of attitudes. In their view, cognitive structure, a person's beliefs determine person's attitudes.

When evaluating the cognitions that determine attitudes, Ajzen and Fishbein (1980) emphasised the importance of extracting beliefs that match with the attitude in terms of the time frame, target, action, and context. This interrelationship is important because a lack of correspondence may attenuate the interrelationships between beliefs, attitudes, intention, and behaviour. While the two authors suggested behaviour can be changed through perceived behavioural control, and then have impact on attitude, this cannot be seen clearly in their model.

2.6.2 THEORY OF PLANNED BEHAVIOUR

Ajzen proposed the theory of planned behaviour in 1985 (Ajzen, 1991). This theory was developed from an earlier theory of reasoned action by Fishbein together with Ajzen himself in 1980. The theory of planned behaviour (Figure 2.4) has become one of the most persuasive and popular frameworks for the study of human actions (Ajzen, 1991). According to this theory, human behave within following three kinds of considerations:

- *Behavioural beliefs*: beliefs about the likely consequences or other attributes of the behaviour; they produce a favourable or unfavourable attitude toward the behaviour,
- *Normative beliefs*: beliefs about the normative expectations of other people; they result in perceived social pressure or subjective norms, and
- *Control beliefs*: beliefs about the presence of factors that may further or hinder performance of the behaviour; they give rise to perceived behavioural control, the perceived ease or difficulty of performing the behaviour.

Generally, an adequate amount of actual human control over their behaviour might carry out their intentions when the opportunity arises. Intention is considered as the immediate antecedent of behaviour.

Ajzen (1991) argued that self-efficacy demands do not necessarily correspond to beliefs about internal control as a unitary core parameter, nor to distinguish between self-efficacy and controllability by entering different parameters therefore, controllability expectations have no necessary basis in the perceived operation of external parameters. Instead, it was suggested that self-efficacy and controllability may both reflect beliefs about the presence of internal, as well as external factors. Depending on the intent of the finding, a decision can be made to aggregate all items, treating perceived behavioural control indices into the prediction equation.

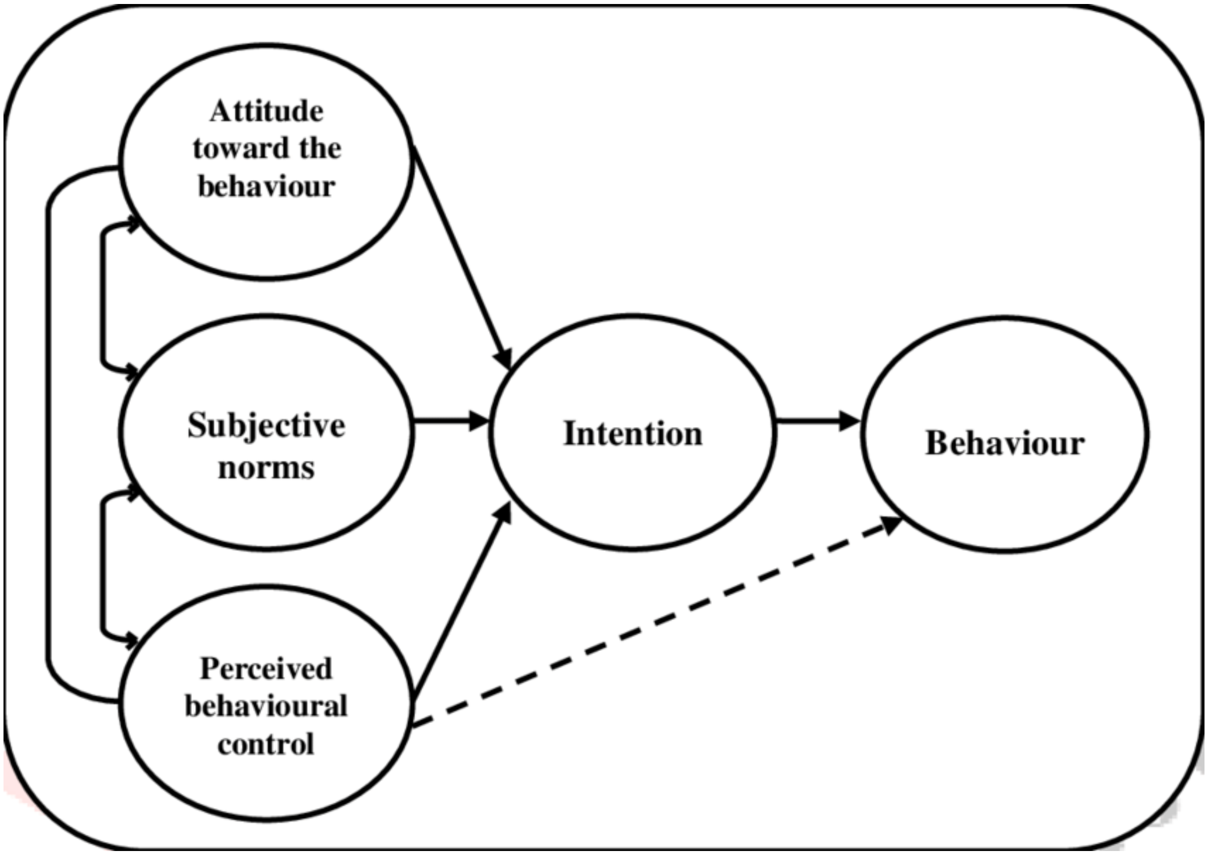

Figure 2. 4 Theory of Planned Behaviour (Ajzen, 1991)

A counterargument against the strength of the interrelationship between behavioural intention and actual behaviour has raised as the results of other studies discuss that because of circumstantial limitations, behavioural intention does not necessarily lead to actual behaviour (Van Raaij & Verhallen, 1983). By adding this concept, they developed and revised the theory of reasoned action in 2010, to address non-volitional behaviours for predicting behavioural intentions and real behavior, and to predict how humans will behave based on their attitudes and behavioural intentions.

This theoretical position can form the basis for this current study is that attitudes impact and inform human behaviour. Some occupant behaviour can be predicted based on their beliefs, attitudes, and knowledge; however, time is important as lack of correspondences can weaken this interrelationship. It is also important to study the level of impact that some behaviour can have on people's attitudes.

2.6.3 DNAS FRAMEWORK

Turner & Hong (2013) argued within their Driver-Needs-Action-Systems (DNAS) framework (Figure 2.5) that green buildings cannot meet the expectation of design performance criteria. Therefore, technology by itself cannot guarantee high environmental performance. Occupant behaviour and actions impacts are really ignored throughout the project lifecycle from inception all the way to completion and operation of buildings. The impact of the behaviour of occupants on building energy consumption can be described using four main components: i) drivers, ii) needs, iii) actions, and iv) systems (Figure 2.5). Environmental occupant behaviour drivers are mainly: a) biological, b) societal, c) environmental, d) physical and e) economical in nature; five elements which can reveal the stimulate certain occupant environmental behaviour.

A driver prompts a building's occupants to perform action or in-action with a building system, which is impacting the energy consumption of a building. Environmental factors, such as climate, weather and indoor and outdoor conditions are all major drivers behind the response of occupants to their environments (Turner & Hong, 2013).

Needs represent the occupant physical and non-physical requirements that must be met in order to ensure the satisfaction of the occupants with their environment. Occupants will have certain criteria or expectations regarding their environment that relate to their overall comfort. When the state of physical discomfort exceeds the tolerance of the occupants, it causes a psychological response, which prompts those occupants to perform actions to adjust their environment (Turner & Hong, 2013). Zachary et al. (1998) agree with this model saying that the *'outside world'*, made up of visual, acoustic and thermal environments, all of these are conceptualised as human sensations and perceptions which translated these *'inside world'* inputs into cognitions (drivers, needs, etc.) that can simply lead people into physical actions.

Actions are the outcome of interactions with systems or activities that the occupants can conduct to achieve environmental comfort, such action might be an interaction with a system in which the occupants assume that their action will restore comfort (Turner & Hong, 2013).

Systems refer to the equipment or systems within a building with which the occupants may interact to restore or maintain their environmental comfort, for a system to affect the occupant-related energy performance of a building, it needs to be acted upon or controlled by its occupants (Turner & Hong, 2013). The researchers also contextualised DNAS framework while describing the DNAS ontology in the form of an extensible markup language (XML) schema known as obXML (occupant behaviour XML) as well as discussing the potential applications (Hong et al. 2015).

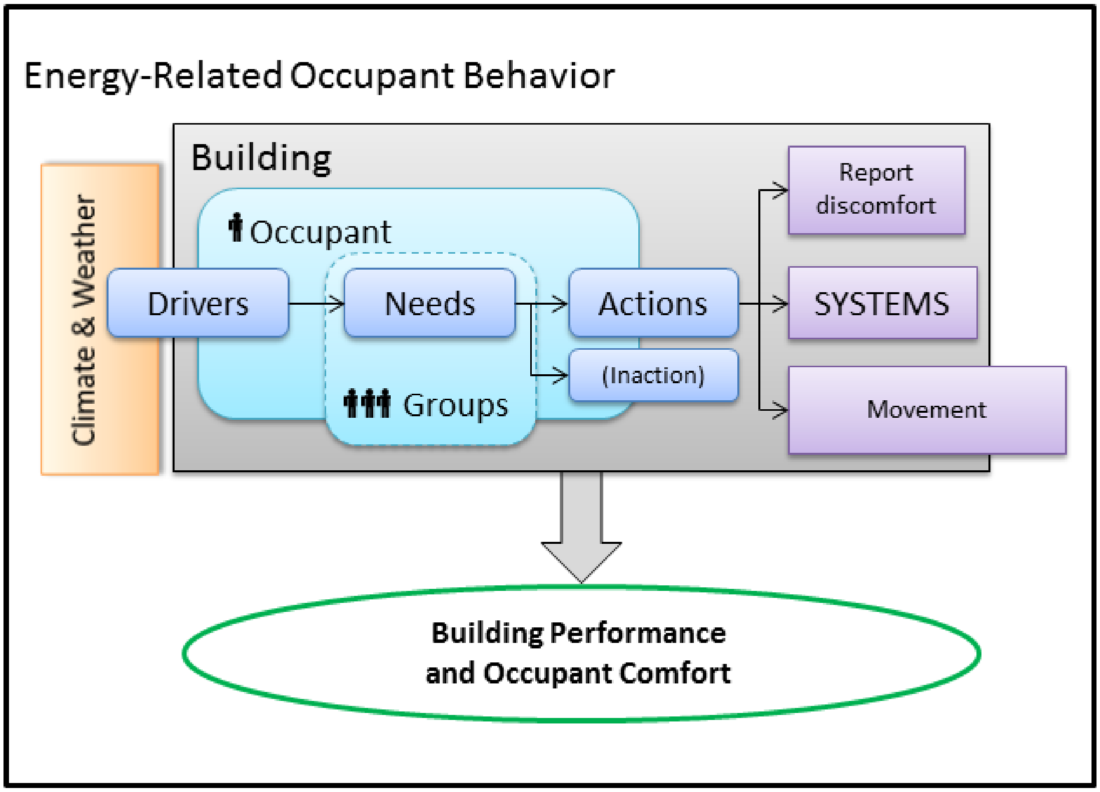

Figure 2. 5 DNAS occupant behaviour framework (Turner & Hong, 2013)

2.6.4 CONSUMER-TECHNOLOGY INTERACTION (CTI) MODEL

Figure 2.6, the Consumer-Technology Interaction (CTI) model by Groot-Marcus et al. (2006) provides a model showing the building and its environment interaction. This model is based on some technology-oriented systems in which material and immaterial factors are set to satisfy occupant needs in their relationship with the environment. The focus on this model is the interaction between human and material factors. Sustainable building design and technologies can be perceived as innovative disruptive technology since occupants do not have any experience with these systems and sustainable approaches.

When a technology is not functionally compatible, the performance level of an activity is altered and may become incompatible with the occupant living standards (Groot-Marcus et al., 2006). Environmentally conscious occupants might accept a lower comfort level when using a low-pressure showerhead, because they have changed their standards of living, as shown in Figure 2.6. These changes in standards of living can happen more frequently through behaviour change. Like Fishbein and Ajzen (1975, revised 2010) in Figure 2.3, the CTI model study (in Figure 2.6) also reveals that there is a need for quick correspondence in order to have changes in attitude and standards of living which can change behaviour. The CTI model also covers the factors such as social norms and values, which are the determinants of behavioural change. At the same time, the *'needs'* shown in the model suggested by Turner & Hong (2013) in Figure 2.5 are those associated with the standards of living actions designed to maintain occupant comfort and satisfaction.

If occupants are required to change their standards of living, such an imposition might lead them towards modifying their 'normal' comfort levels; a change that some environmentally conscious occupants might accept. It is important for this research study to identify the other factors that can encourage the majority of a building's occupants to change their standards of living slightly, to demonstrate better environmental behaviour.

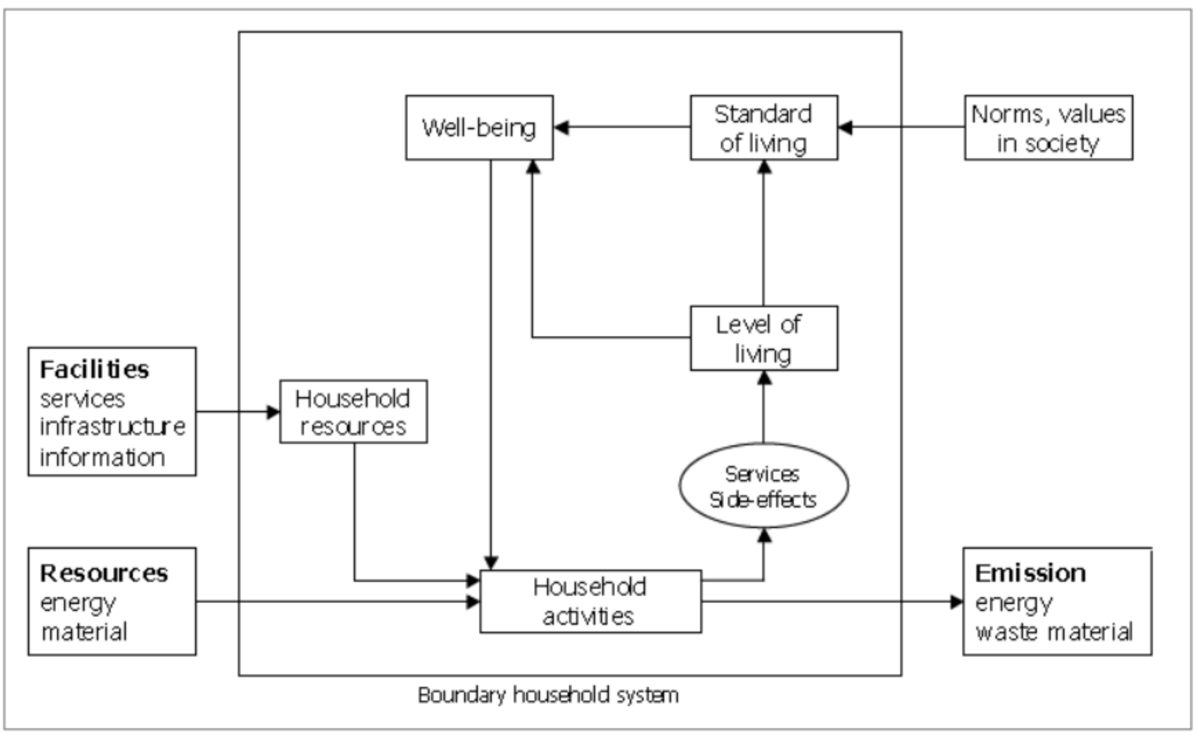

Figure 2. 6 Consumer-Technology Interaction (CTI) model (Groot-Marcus et al., 2006)

2.6.5 ENERGY USE BEHAVIOURAL MODEL

Van Raaij and Verhallen (1983) proposed a behavioural model (Figure 2.7) while identifying different parameters affecting occupant behaviour, as shown by continuous lines. In this model, a household's energy use is influenced by environmental behaviours. It can be seen that there are chain lines showing the flow of received feedback from energy use in the form of financial incentives and information that are designed to influence occupant Attitudes, Knowledge and Behaviour (AKB). On the other hand, other factors such as home characteristics have a direct influence on energy use, and they may also influence occupant behaviour. Van Raaij and Verhallen (1983) believe that if behaviour can be changed in a more energy-conserving direction, we can expect that occupants will develop energy-conscious attitudes, although the reverse is not always true.

In both this model and the model which was developed by Fishbein and Ajzen in 1975 and revised in 2010, attitude has a one-way impact on behaviour. In this model, Van Raaij and Verhallen (1983) stated four intervening factors between behaviour and attitude: i) *acceptance of responsibility,* ii) *energy knowledge,* iii) *perceived effectiveness of one's contribution and* iv) *cost-benefit trade-offs.* The model also involves feedback from the evaluation of energy use and behaviour, which can create the feedback information. This information covers two different important aspects of behavioural change. As shown in Figure 2.7, there are three chain lines going out from feedback information: lines A, B and C. There is habitat formation (A) which can have a direct impact on environmental behaviour. This information can also be used as a learning process (B) which can raise levels of energy awareness and add to the occupant environmental knowledge and acceptance of occupant responsibility. Internalisation (C) of such feedback information can change occupant lifestyles and beliefs, resulting in alterations to environmental attitudes and social norms. The best measure of energy use in their study is energy bills which show the amount of electricity, gas and water consumption, but there is no specific measurement separately for measuring lighting or the consumption rates of home appliances and systems. Therefore, the energy demands from appliances are not considered in the study by Van Raaij and Verhallen (1983).

The researchers emphasised that when the feedback period is shorter, then the feedback information will become more effective; a conclusion is in line with the research findings from Ajzen & Fishbein (1980) regarding correspondence in terms of time. Van Raaij and Verhallen (1983) also argued that changes in attitudes can be led into behavioural changes. They suggest that positive attitudes toward energy savings can be materialized in better environmental behaviour under the circumstances that the economic trade-offs and cash incentives are favourable for energy savings. They also suggested that information about the costs of certain environmental behaviours may be able to directly change behaviour. Van Raaij and Verhallen (1983) mentioned that the intervening construct attitude and behaviour are led to the following hypothetical conditional roles:

- If occupants have the possibility to perform energy conscious behaviour,
- If occupants accept their responsibility for energy conservation,
- If occupants have enough knowledge regarding the consequences of their behaviour on their energy supply,
- If occupants perceive their contribution to energy conservation to be effective, and
- If the economic and behavioural cost-benefits for energy conservation are positive.

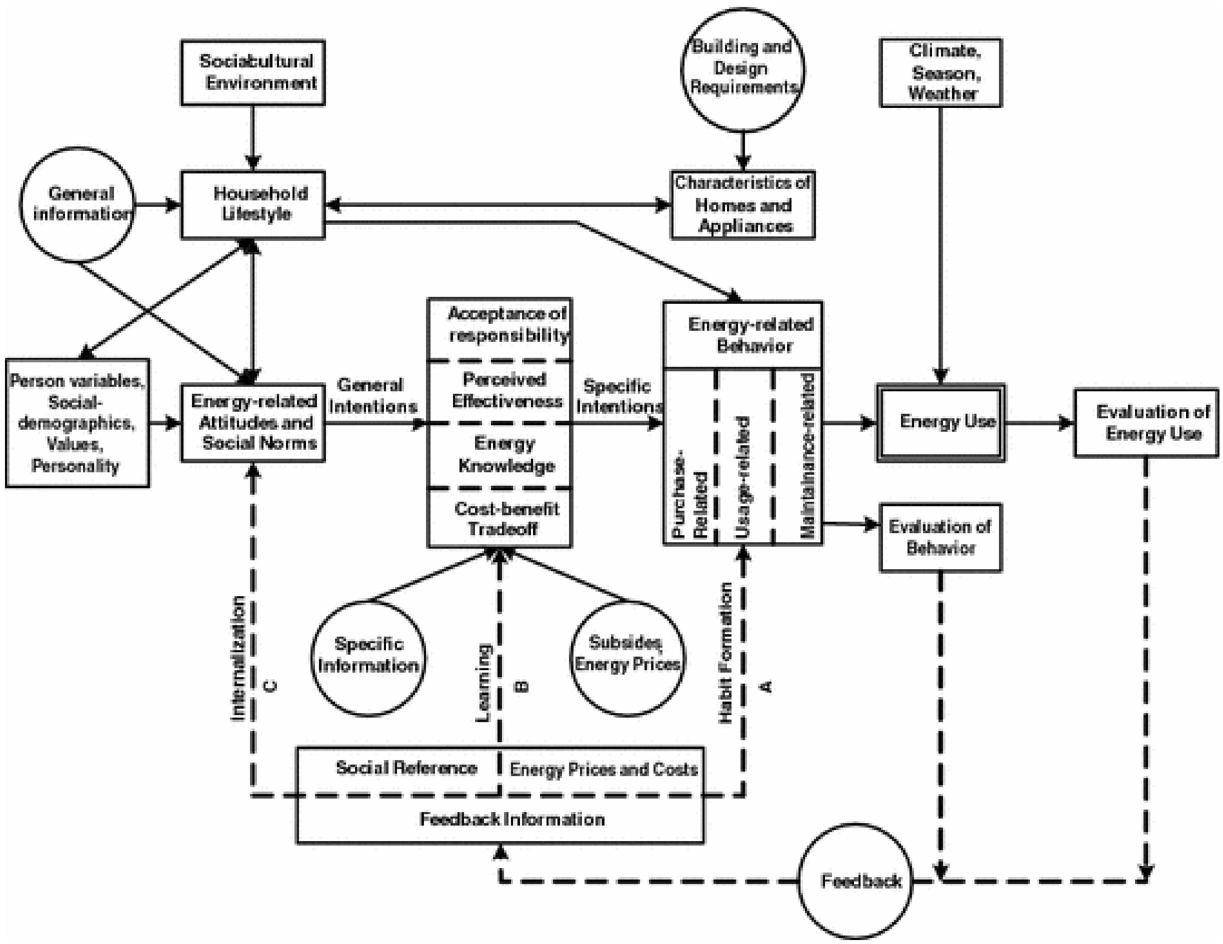

Figure 2. 7 A behavioural model of residential energy use (Van Raaij & Verhallen, 1983)

2.7 KEY FINDINGS

The total categories, sub-categories, points, and mandatory credits in LEED aim at assessing the sustainability of a building. Particularly LEED total points and mandatory credits were doubled in version 4 as compared to version 2; besides adding two more categories, however, LEED still does not show a very strong inclusion of occupant behaviour during building post-occupancy phase.

BREEAM is considered the strongest rating system while addressing the issues related to society and environment through an intensive POEs process under management category known as *'after care'*. All the BREEAM assessment rating systems mainly concentrate on the environment while society receives less attention. Only BREEAM has one sub-category considering economic issues regarding energy consumption. Therefore, approaches such as Soft Landings seems as an effective approach in BREEAM which mainly aims at troubleshooting the building after operation to bridge the environmental and energy performance gap.

Government in the UAE has ambitious visions for national development and a commitment towards high-quality economic, social, and environmental outcomes. There is a shared responsibility amongst the stakeholders including governmental authorities, building designers and operators towards providing better education and training focused on changing occupant lifestyles and environmental behaviour.

The findings revealed that the occupants are forgiving towards energy conservation practices in green buildings although they have the higher satisfaction level in green buildings than in conventional/non-green buildings.

Most of the models and frameworks cited in this Chapter captured the stochastic and reactive nature of human behaviour happening in a complex environment. Some of the models and frameworks have focused on occupant environmental behaviour.

The characteristics from the existing reviewed models and frameworks that influenced this study is presented in Figure 2.8.

Reviewed Behavioural Models & Frameworks	Characteristics
Theory of Reasoned Action (Fishbein & Ajzen, 2010) Figure 2.3	• Behaviour is based on occupant attitudinal, normative beliefs and background. • Behaviour might be predictable. • Only needs cannot affect occupant environmental behaviour. • It is one of the most influential and popular conceptual frameworks. • It is not suitable for complex systems.
Theory of Planned Behaviour (Ajzen, 1991) Figure 2.4	• It treats perceived behavioural control as a unitary core factor while there is no impact from behaviour on attitude. • Behavioural intention does not always lead to actual behaviour. • Self-efficacy expectations do not necessarily correspond to beliefs about internal control factors, and controllability expectations have no necessary basis in the perceived operation of external factors.
DNAS Occupant Behaviour (Turner et al., 2013) Figure 2.5	• Relationships between external environmetal factors that can create needs might lead to certain behaviour. • No other external factors are considered and there is no discussion about interrelationship between attitude and behaviour. • While need is important to affect actions, occupant behaviour is still part of the core of this framework.
Consumer-Technology Interaction (CTI) (Groot-Macus et al., 2006) Figure 2.6	• It shows interaction between technology and behaviour. • It reveals interaction between material factors and human. • If the technology is functionally incompatible, the performance level of an activity may become incompatible with the desired living standards. • Occupants can change their standards of living, which can lead to changes in their needs and their behaviour.
Residential Energy Use Behaviour (Van Raaij & Verhallen, 1983) Figure 2.7	• Four intervening factors between behaviour and attitude are: acceptance of responsibility, energy knowledge, perceived effectiveness of one's contribution and cost - benefit trade-off. • Home characteristics and systems can improve the behavior towards energy consumption reduction. • Attitudinal changes can lead to behavioural changes. • Information about energy costs can change behaviour directly.

Figure 2. 8 Summary of reviewed behavioural models and frameworks

2.8 CONCLUSION

After reviewing all the findings in this Chapter and knowing that LEED lacked inclusion of occupant behaviour together with learning from existing models and frameworks for behavioural change, the researcher has identified the following further studies to address the environmental and energy performance gap revealed in the literature review:

- It would be useful to compare the occupant behaviour between conventional and LEED-certified buildings, in order to understand whether green building occupants are more forgiving or concerned about environmental behaviour and energy usage reduction than occupants of conventional buildings in the UAE, this finding can is a good basis to know in what direction the research study should be continued.
- The literature reviews also stressed the need to organise a well-structured Post Occupancy Evaluation (POE) survey within LEED-certified buildings, which are perceived to be green and environmentally capable buildings. Such a survey if combined with interview could help to identify the reasons behind the environmental and energy performance gap caused by occupant behaviour as well as better understanding about motivational factors that can help to improve such behaviour to achieve the potential savings.
- An investigation focused on the interrelationships between factors affecting occupant behaviour, such as attitudes and knowledge, would be beneficial in gaining an understanding the impact of such parameters while including occupant environmental behaviour in LEED certification process.
- Finally, as confirmed by the literature review, there is a scope for understanding and improving building occupant environmental behaviour (BOEB). This initiative would stimulate occupant behaviour in the UAE LEED-certified buildings, encouraging them towards more environmentally-friendly fashion.

The interrelationship between Attitude, Knowledge and Behaviour (AKB) shown in Figure 2.7 are the parameters as the basis of analysis in this research study to review the interrelationship between them. On the other hand, Figure 2.5 is a very good basis of indicating factors that are important to change behaviour however, '**Motivation**' is an important factor missing in these models to change occupant environmental behaviour.

CHAPTER 3 - RESEARCH METHODOLOGY

3.1 INTRODUCTION

This Chapter presents the main research methodology as well as explaining the choices of methodologies adapted for this study. First, research paradigms are discussed to decide the appropriateness of the paradigm chosen for this study. Secondly, research approaches are discussed to decide the most suitable research model to maximise the effectiveness of information collection process. Thirdly, data collection and analysis techniques are finalised. The whole process will be contextualised by creating a flow diagram of key stages involved in the proposed research plan.

3.2 RESEARCH PARADIGMS

The supporting concept of paradigms has influenced the philosophy and methodology of the social sciences and played a fundamental role in science. A paradigm is considered as a whole system of thinking (Neuman, 2011).

A paradigm includes the accepted theories, traditions, models, approaches, frames of reference, body of research and methodologies relevant to a field or area of interest. It is therefore a framework for observation (Creswell, 2009).

The basis of the qualitative and quantitative approaches to information gathering extends into different paradigms: positivism and post-positivism (Cohen et al., 2007; Denzin & Lincoln 2005). Interpretivism is another paradigm while some believe that it is merely a sub-division of post-positivism.

3.2.1 POSITIVISM

Positivism is widely known as an approach to social research that aims to apply the natural science model of research for societal investigations and explanations (Denscombe, 2008). Positivism consists of a belief based on the assumption that methods and scientific procedures are applicable to the social sciences. This view suggests that the objects of the social sciences, humans and their behaviour, are suitable as the focus for scientific methods (Denzin & Lincoln, 2005).

Within the positivist approach, knowledge can only be produced through direct observation. There is no place for phenomena which cannot be observed; for example, human behaviours and attitudes cannot be accepted as valid evidence if they are not through scientific methods.

Due to some limitations of the positivist approach in terms of qualitative data adoption, some alternative approaches became more widespread; a development known as post-positivism, which the researcher reviews in the following section.

3.2.2 POST-POSITIVISM

Dissatisfaction with positivism elevated the demand for post-positivism. Post-positivism has gained significant credibility with social science researchers. Creswell (2009) mentioned that the post-positivism is an extension of positivism, it represents the thinking after positivism, challenging the traditional notion of the absolute and objective truth of knowledge in the social sciences. Post-positivists believe that positivism is difficult for different kinds of social sciences (Glicken, 2003). Post-positivists apply subjective measures in order to gather information. The researchers honesty could be a problem in this type of research, as being subjective in a post-positivistic research study might negatively influence the data, however, it can also offer the ability to do research on a small scale by using very creative methodologies for social scientists (Glicken, 2003). The researcher in this study prefers to rely on her findings rather than only focusing on certainty and absolute truth therefore, she has concluded that the post-positivist paradigm is suitable to fulfill the purpose of this study.

There are some limitations within post-positivism, which led to the development of the interpretivist approach.

3.2.3 INTERPRETIVISM

The interpretive paradigm aims at understanding people (Babbie & Mouton, 2010). There are two different types of science: i) the natural sciences, and ii) the human sciences. All humans work towards making sense of their worlds and to interpret, create, give meaning, and rationalise their daily actions. Hence, interpretivism focuses on exploring the social phenomena complexities with a view towards gaining understanding (Babbie & Mouton, 2010). The purpose of research in interpretivism is to be able to understand and interpret daily events and social structures, because the meanings humans give to their lives can be discovered through interviews, and not solely through quantitative analysis.

Interpretivists reject the concept that there is no value in research if the researcher's interpretation is socially constructed and reflecting his/her observations. Blumberg et al. (2011) state that human interests channel our thinking and influence how the world is investigated, and how knowledge is constructed. Thus, the researchers should target the processes of subjective interpretation, acknowledging the motivations, interests, intentions, beliefs, values, and reasons, meaning-making and the self-understanding of the individuals (Blumberg et al., 2011). The use of these methods points to the use of qualitative data-gathering methods, which suggest that the data are generated mainly through interactions such as interviews.

Based on interpretivist arguments, an objective observation of the social world is not possible, as it is constructed by intentional behaviour and actions. Indeed, it is true that building occupant behaviour varies in different regions and social environments. Many different factors might influence people's attitudes and behaviour because their social worlds are relative to all other events and experiences. Nevertheless, the researcher prefers to gain valuable analysis by focusing on both approaches: a) collecting and analysing numerical data while b) discussing the rationale behind those data through her own findings gained from interviewing building occupants and operators. The researcher in this study believes knowledge can be developed and a theory can be built by developing ideas from observed numerical data, as well as from interpreted social constructions. As a result of this view it was decided that post-positivism is the most suitable paradigm to inform this research study.

3.3 RESEARCH APPROACHES

The most obvious differences between research approaches are the seemingly opposed qualitative and quantitative information gathering approaches.

There are no set rules and some qualitative studies may have a deductive orientation. It is by no means that these methods are or should always be linked with those logical approaches. In the deductive approach, a hypothesis is developed and then there will be a strategy to test that hypothesis (Saunders et al., 2009).

3.3.1 THE QUALITATIVE APPROACH

Qualitative research is well known within social science because it enables researchers to examine, analyse and interpret behaviour-related observations in a manner that does not involve mathematical models (Miles et al. 1994). In other words, this research model is informed by a certain degree of subjectivity.

Qualitative research is more subjective compared to quantitative approach and often uses an inductive approach to gain insights into people's attitudes, behaviour, concerns, motivations, culture, and lifestyle. However, the analysis of such data is more difficult due to open-ended answers. The qualitative method is sufficiently flexible to allow the use of different collection methods and measuring instruments, such as: i) focus groups, ii) open-ended, semi-structured and structured interviews, iii) observations and iv) documents and texts analysis. The selected participants in this research will be involved in individual interviews rather than focus groups. The reason this format has been chosen is because the selected occupants might avoid talking about their lack of knowledge or information in front of their neighbours. Individual face-to-face interviews, when done well through semi-structured questions, can encourage the interviewees to talk more, thereby helping the researcher to understand the intentions and beliefs of those occupants. These types of questions can keep the discussion within the researcher's desired area while allowing the interviewees to express their opinions about the topic or the reasons behind the behaviour of interest.

3.3.2 THE QUANTITATIVE APPROACH

Quantitative research requires the researcher(s) to objectively evaluate the data, which consist of numbers, while trying to exclude any bias from the researcher's opinion or input. In other words, the quantitative paradigm is a type of research in which the researcher decides: i) what to study, ii) asks specific, narrow questions, iii) collects quantifiable data from participants, iv) analyses these numbers using statistics, and v) conducts the inquiry as objectively as is viable. In this research, firstly the quantitative method makes use of a structured questionnaire to help the researcher to test a hypothesis using numerical data and find the significance of interrelationships among measured variables, and later to use the data for further analysis through the process of Structural Equation Modelling (SEM) technique in AMOS software.

3.3.3 MIX METHOD

Mix method research is being regarded as the integration of qualitative and quantitative approaches, which gives it a very broad range of applications. This research method is known by different names such as: a) integrated approach, b) hybrid approach, c) combined methods, d) methodological pluralism and e) triangulation. Both quantitative and qualitative approaches have clear strengths and weaknesses. Human sciences research often contains the combination of both qualitative and quantitative methodologies (De Vos et al., 2011).

Mix-methods research may pose a danger of a dilemma arising from two main areas. The first dilemma is whether to integrate or compliment the methodologies. Integration gives the two approaches equal emphasis while complimenting will give to one more emphasis than the other, similar in this research study, as there is more emphasis on survey analysis as the quantitative approach and then the qualitative approach in the form of interviews becomes as the complementary part. The second dilemma is the sequence of the research, for example whether the research should start with qualitative and finish with quantitative or vice versa (Brannen, 1992). In this research, the researcher decided to start with quantitative approach and finish it with the qualitative approach as the complementary part. There is flexibility to choose between different methods such as interviews, surveys, etc. and experimental research to compliment and enable researcher to find about reasons behind some of the answers in survey analysis.

Leedy and Ormrod (2005) agree with Babbie and Mouton (2010) that research methodology mainly relates to the researcher's general approach in conducting their research project. Therefore, it is crucial for researchers to decide which research method is suitable for their study topic and therefore, different approaches were carefully reviewed to achieve appropriate understanding and to make informed decisions for this study.

3.4 RESEARCH METHODS ADOPTED FOR THIS STUDY

As discussed earlier in this Chapter post-positivists are more open to different methodological approaches, and often include qualitative, as well as quantitative methods. Therefore, in this study the decision was reached to use quantitative methods to gather measurable numerical data to investigate the observed variables which can measure unobserved variables such as occupant behaviours and attitudes, and then find the rationale behind some of those numerical data through a qualitative approach. Therefore, this research adopted a mix method approach, informed by a post-positivist view.

From a researcher's perspective, it is probably more appropriate to speak about verification by starting with the research problem in mind and later seeking the best mix of approaches to find the reasoning behind some of the answers to the questions. During the early stages of this research, data collection began via the quantitative method, featuring a questionnaire survey. This instrument provided reliable statistical data needed to confirm the interrelationship between the observed and latent variables. That information allowed the researcher to gain a better understanding of different factors affecting occupant behaviour and their preferences to behave in a certain way. Later the research moved on to a qualitative orientation by using interview questions to clarify and establish a better understanding of the reasons behind some of the building occupant behaviour and to identify factors that can be used to motivate the building occupants to change or improve their behaviour.

Between different approaches within the qualitative data collection model the researcher decided to have one-o-one interview sessions. Other practices, such as a focus group, could decrease the level of comfort for occupants, as they might feel uncomfortable talking about their behaviour and their reasons in front of their neighbours. To keep the data collection process confidential, the researcher found face-to-face private meetings to be more suitable than any alternative options. In this way, she could encourage participants to feel more comfortable to express their feelings and opinions, while their answers might vary in response to some of the questions. In the semi-structured interviews, the researcher set the similar questions for all participants, but some answers could be yes/no, and some might expand upon their responses; in other words, the types and usefulness of responses may vary.

The rationale for choosing a mixed methods research design for this research therefore was to:

- Generate deeper and broader insights into the topic of interest.
- Facilitate a better understanding of the interrelationship between variables.
- Explain opinions and reasons behind the behaviour of different occupants.

3.5 RESEARCH DESIGN

Research stages in this study are as follows:

- The literature reviews present information relating to the development of green buildings, the performance gaps within these buildings and the review of existing occupant behavioural models and frameworks.
- Data collection for a pilot study to compare the occupant environmental behaviour between LEED-certified and conventional buildings. The main survey with concentration on LEED-certified building occupant behaviour and interviews with some of the building occupants and operators, in order to better understand occupant environmental behaviour.
- Data analysis was done through SPSS for the survey questionnaire, with the data later transferred to AMOS for SEM technique to analyse the interrelationships between latent variables; occupant environmental Attitudes, Knowledge and Behaviour (AKB).
- BOEB model was required to be developed whether the hypothesis is confirmed due to the fact that LEED doesn’t include occupant behaviour and therefore, there is a need to promote and improve occupant environmental behaviour for generating environmentally responsible occupants while assessing Attitude, Knowledge and Behaviour (AKB).
- The developed BOEB model will be subject to expert validation to provide feedback on the BOEB model’s applicability of and barriers to its implementation as well as recommendations to improve the model.

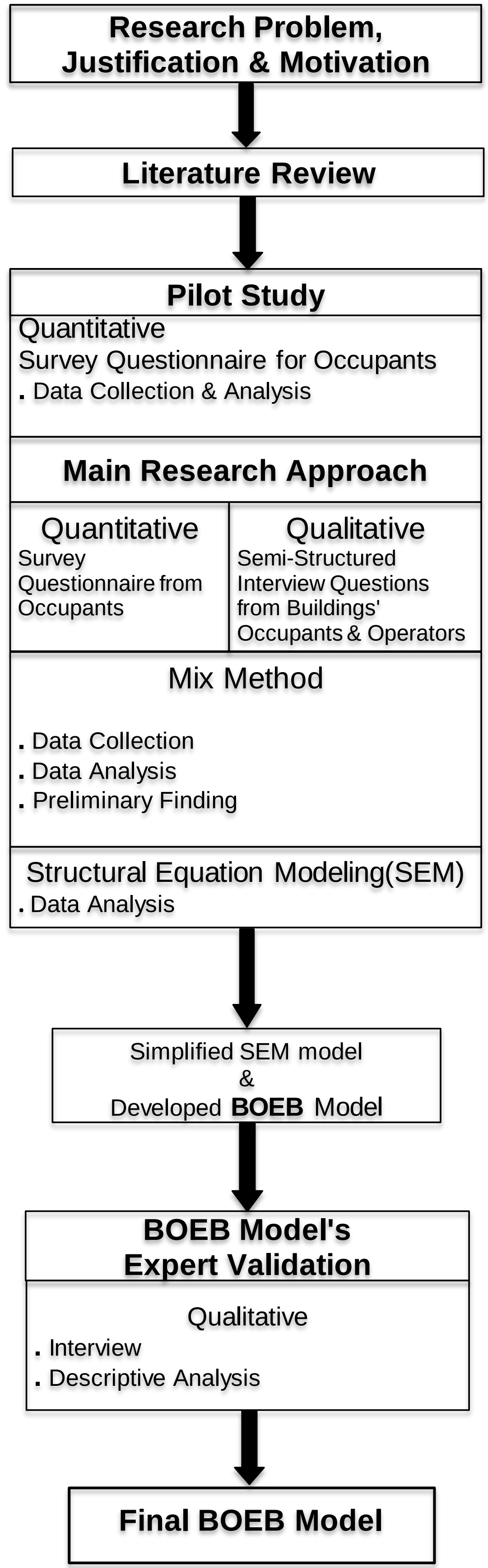

Figure 3. 1 Research design

3.5.1 DATA COLLECTION FOR PILOT STUDY

Findings in literature review in Chapter 2 revealed that people living in green/ LEED-certified buildings do not necessarily become green occupants. However, those living in conventional buildings might behave in a more environmentally-friendly way due to their background and eco-centric knowledge. Therefore, there was a need for this pilot study to review whether occupants in the UAE LEED-certified buildings are greener than those living in the conventional buildings. The focus of this pilot study is to explore how occupants understand the buildings they live in and the role such knowledge plays in shaping their behaviour. This study result can confirm the findings found in the literature review that "buildings don't use energy, people do" (Janda, 2011). It is argued that in order to gain the maximum efficiency in green buildings, occupants should also be green and behave in an environmentally-friendly fashion.

Building recruitment and population

Two residential buildings were recruited for participation in the study; one LEED-certified (Trafalgar Central building CBD8 located in International City, Dubai-UAE, Silver-certified; Figure 3.2) and one conventionally designed (Spain Cluster S16, residential building located in International City, Dubai-UAE; Figure 3.3).

Data analysis

A total of thirty from both building occupants (15 occupants in each building) accepted to complete five survey questions. One of the important aspects of the data collection process in a survey was how to send the questions to potential participants and how the responses were to be received from the invitees. The decision was to approach them individually and ask them to spend some time answering 'Yes' or 'No' to the 5 following questions:

1. Do you use any type of heating systems/ equipment during the wintertime?
2. Do you set the thermostat during the summertime?
3. Do you set the thermostat during the wintertime?
4. Do you use low energy bulbs?
5. Do you leave your electronic appliances on standby mode?

Figure 3. 2 Trafalgar Central (TC), International City, Dubai-UAE

Figure 3. 3 Spain Cluster S16, International City, Dubai-UAE

A total of 15 occupants responded to the survey from Trafalgar Central building representing a response rate of 21.1% (15 out of 71 agreed to participate in the study) and 15 occupants from Spain cluster building with a response rate of 46.8 % (15 out of 32 accepted the invitation) as the researcher preferred to have same number of participants from each building for easier comparison.

3.5.2 DATA COLLECTION FOR THE MAIN STUDY

The aim for the main research study was to further review the occupant behaviour in green LEED-certified buildings, because the findings from the pilot study shows those living in green buildings do not necessarily behave in an environmentally-friendly manner. This finding leads the researcher to investigate more about occupant behaviour in LEED-certified buildings.

Questionnaire design

The design of the questionnaire was based on studies on POEs survey questions and other similar research studies questions (NASA POE guidebook 2014; Riley et al. 2010). Accessing such resources helped to address the identified questions relevant to this research study. The questionnaire and its questions were designed to ensure that they were simple, short, and attractive to respondents. More details about the survey questions can be found in Appendix B. The questionnaire has 5 sections, starting with questions about occupant backgrounds, followed by environmental-related attitude. Next the occupant environmental behaviour is investigated, followed by understanding about their comfort and satisfaction level. Finally, the effectiveness of the management system, training and knowledge sharing in their buildings were investigated. The questions had to address the challenges regarding occupant environmental attitudes and knowledge which influences their environmental behaviour.

For simplicity, the structure of the questionnaire was made as easy as possible for the respondents to manage and comprised of short questions with multiple short answers. Respondents were mostly asked to provide their answers by checking the box that best represented the opinion or information relevant to their background, attitude, behaviour, satisfaction and knowledge. The questionnaire was rigorously tested for ease to manage and understandability for the volunteer respondents. First the questionnaire was sent to 10 occupants to test and finalise the appropriateness of the questions and answers. The researcher made very few modifications after completing the testing procedure. For example, there was no ‘Don’t know’ option within multiple choices and after observing lack of answers to some of the questions and knowing that occupants don’t know the answer, the researcher decided to add ‘Don’t know’ to avoid missing values while analyzing the data in SPSS and AMOS. All 31 questions in five sections were produced in hard and soft copies.

Survey Sampling

By the time of setting the research study, there were 15 LEED-certified residential multi-family buildings and 14 villas with approximately1724 units with less than 60% occupancy rate. By investigating through casual chats with BOs, there were approx. 1034 occupants in those LEED-certified units in the UAE in 2014 (USGBC, 2014). By calculating the Sample Size with 5% margin of error, 95% confidence level and 50% sample proportion:

Sample Size (X) = Distribution of 50% / ((Margin of Error / Confidence Level Score) Squared = $0.5/ (0.05/0.95)^2 = 0.5/ 0.00277008 = 180.500202$

By putting the Sample Size (180.500202) in True Sample formula:

$$n = X * N / (X + N - 1)$$

while ‘n’ is True Sample, X is Sample Size and N is Population, True Sample would be: 180.500202 x 1034/ (180.500202+1034–1) = 186,637.209/1,213.5002 = 153.800724 ~ 154.

Based on the information provided by BOs, 265 units were considered more accessible and therefore, all 265 units were contacted to assure the response number above 154. If 154 occupants out of 265 targeted units would not participate, then the researcher had to target more units to reach to the minimum acceptable threshold/ True Sample. The questionnaire was administered by emails or was hand delivered. BOs helped to target occupied units. Respondents were reminded every three weeks by the researcher or a BO through follow-up emails, or notes at their door, in order to improve the response rate. If a potential candidate was reminded 2 times, but still declined to respond then that occupant was removed from the list of potential participants. 203 occupants responded to the survey with valid answers: making a response rate of 76.6%.

Building selection

Most occupied LEED-certified buildings in 2014 were in ‘Dubai International City’, four of them were recruited for this research study as shown in Figures 3.4 – 3.7 & Table 3.1:

Figure 3. 4 Prime Residency I (PR I), International City, Dubai-UAE

Figure 3. 5 Prime Residency II (PR II), International City, Dubai-UAE

Figure 3. 6 Trafalgar Central (TC), International City, Dubai-UAE (Same as Figure 3.2)

Figure 3. 7 HDS Sun Star II (HDS SS II), International City, Dubai-UAE

Table 3. 1 Information about 4 LEED-certified buildings

Fast Facts	**PR I** Figure 3.4 164 units	**PR II** Figure 3.5 164 units	**TC** Figure 3.6 160 units	**HDS SS II** Figure 3.7 140 units
LEED Certification	SILVER New Construction (NC) V2.2	GOLD New Construction (NC) V2.2	SILVER New Construction (NC) V2.2	SILVER New Construction (NC) V2.2
Square Feet	251,176 sq. ft. Residential Building	251,176 sq. ft. Residential Building	214,059 sq. ft. Residential Building	176,485 Sq. ft. Residential Building
Construction Cost	$76 / square foot	$78 / square foot	$73.5 / square foot	Unknown
Completion Date	March 2011	March 2011	July 2011	September 2012
Certification Date	June 2011	October 2011	August 2012	September 2013
Estimated Savings & Benefits	17.5% Savings on Energy Use 35.4% Savings on Potable Water Use 20.9% Materials Use with Recycled Content 43.9% Regional Materials Use	38.6% Savings on Energy Use 35.4% Savings on Potable Water Use 20.9% Materials Use with Recycled Content 43.9% Regional Materials Use	17.9% Savings on Energy Use 41.3% Savings on Potable Water Use 34.38% Materials Use with Recycled Content 41.24% Regional Materials Use	21.3% Savings on Energy Use 31.8% Savings on Potable Water Use 21.0% Materials Use with Recycled Content 13.2% Regional Materials Use

The key specifications of these buildings are provided in Table 3.1. Three of them are SILVER-certified and the estimated savings for them in Table 3.1, are similar.

Data analysis

Statistical techniques were used to analyse collected data using SPSS software (version 22) to obtain descriptive statistics, frequencies, and means. After that the researcher transferred SPSS data to Analysis of Moment Structure (AMOS) software for running the Structural Equation Modelling (SEM) technique.

Descriptive statistics were used as a set of descriptive coefficients to summarise a given data set, which was a representation of the entire population.

Mean rating statistical technique was selected to analyse participants ratings of the importance of different factors while choosing their homes, by using the numerical values assigned to each factor to calculate their mean scores.

Structural Equation Modelling (SEM) is a statistical methodology which mainly takes a confirmatory (i.e., hypothesis-testing) approach to the analysis of a structural theory. The term SEM conveys two important aspects of the procedure: a) that the casual processes under study are represented by a series of structural (i.e., regression) equations, and b) that these structural relations can be modeled pictorially to enable a clearer conceptualization of the theory under study (Byrne, 2010).

There are different options available for SEM technique such as: LISREL, AMOS, Mplus, EQS, Calis, SEPATH, Tetrad. Among all the available software, AMOS was the most recent statistical package which has a user-friendly graphical interface and became popular as a simpler way of specifying structural models.

Byrne (2010) indicates the following as some of SEM features that can easily set it apart from the other generation of multivariate procedures:

- First, it gets a confirmatory, rather than an exploratory approach to the data analysis. It lends itself well to the analysis of data for conclusive purposes, while, most other multivariate procedures are essentially descriptive by nature (e.g.: exploratory factor analysis).

- Second , whereas traditional multivariate procedures are incapable of either assessing or correcting measurement error, SEM presents explicit estimates of these error variance parameters. It might be used as a more powerful alternative to multiple regression, path analysis, factor analysis, time series analysis and analysis of covariance. It serves purposes like multiple regression, but in a more powerful way which considers the modelling of nonlinearities, interactions, correlated independents, measurement error and correlated error. Multiple latent independents are measured by multiple indicators, and one or more latent dependents. Therefore, applying those methods when there is error in the explanatory variables is tantamount towards ignoring error that may lead to serious inaccuracies, especially when the errors are sizable. Such mistakes are avoided when corresponding SEM analyses (in general terms) are used.
- Third, using SEM procedures can incorporate both unobserved/ latent and observed variables/ indicators.
- Finally, there are not widely and easily applied alternative methods for modelling multivariate interrelations; these important aspects are available while using SEM methodology (Byrne, 2010).

SEM became popular for non-experimental research, where methods for testing theories are not well developed (Bentler & Bonnet, 1980). It can be used to address several research problems involving non-experimental research.

The SEM approach was chosen as it was the most appropriate data analysis method among other statistical analysis methods for this part of the study. It can also consider the measurement errors inherent in subjective operational measurement and this is to define the set of interrelationships in the hypothesized model (Byrne, 2010). With all these features, SEM has become a popular methodology where ethical considerations make experimental design unfeasible (Bentler & Bonnet, 1980; Islam & Faniran, 2005).

According to Hair et al. (1998) SEM usually should be developed through several stages; first to define structural components to identify the measurement components which deals with the interrelationships among the unobserved/ latent variables and their observed variables/ indicators, then to set up a model specification (hypothetical model) based on the aim of the research, after that to evaluate model estimates for validating the structural model variables and finally to modify the model based on potential changes.

Larger sample sizes (100-400) are generally an acceptable threshold for SEM analysis among researchers (Byrne, 2010). Therefore, the sample size of 203 (survey participants) in the current study is considered as an acceptable threshold.

The interview questions design

The researcher was looking at participants answers to the survey questions and was asking them for further explanation or reasons for their choices. For example, the researcher asked them 'You have mentioned there is little threat to the world from climate change, can you please explain more?'. In this way, the open-ended/ semi-structured interview questions were investigated, based on their answers to the survey questions. The role of the researcher during the interviews in this part of the study was more of a casual observer who recorded the information, asked questions, and motivated participants to express their opinions with regards to their answers to research questions. These semi-structured interviews were conducted in order to obtain a greater amount of data and to avoid the simple 'YES' or 'NO' responses; a method of research that is suitable for use with the social sciences.

While the researcher had a theme to be explored the participants were allowed and encouraged to bring new ideas and thoughts to the topic. As the questions are not structured, the researcher was able to tailor and present the questions in different ways. The instructions for the interviewees were created in such a way that the respondents felt quite comfortable about their interview process. The 10 interviewees could skip any of the questions that they were not comfortable to answer or did not apply to them.

Face-to-face interviews were used in all cases, as this method is highly recommended by psychologists for the ability of interviewer and interviewees to interact, thereby allowing a researcher to observe and collect behavioural variations. The interview was mainly a casual discussion around the survey participant's answers and all the additional and useful information during this discussion was noted by the researcher.

Selection of interviewees

Target participants were selected from two populations:

1) Occupants of the LEED-certified buildings: 72 survey participants were contacted, and 10 occupants accepted to be interviewed with participation rate of 13.8% (see Table 3.2). The choice of occupants to be interviewed was purposely based on their answers to survey questions. The aim of the interview was to provide further insights into some of the issues raised from the analysis of the questionnaire survey answers.
2) Building operators (BOs): 5 BOs from all 4 LEED-certified buildings were interviewed (From one of the buildings, two staff accepted to be interviewed therefore, a total of 5 BOs contributed to the interviews - see Table 3.3). The purpose of interviewing BOs was to better understand the relationships between BOs and occupants and the interrelationships between different variables in collected data.

Table 3. 2 Selected Occupants for interview

Occupant No.	Building Name
Occupant 1	TC
Occupant 2	TC
Occupant 3	TC
Occupant 4	PR I
Occupant 5	PR I
Occupant 6	PR I
Occupant 7	PR II
Occupant 8	HDS SS II
Occupant 9	HDS SS II
Occupant 10	HDS SS II

Table 3. 3 Selected Building Operators (BOs) for interview

BO No.	Building Name
BO 1	TC
BO 2	PRI
BO 3	PRII
BO 4	HDS SS II
BO 5	HDS SS II

3.5.3 BOEB MODEL DEVELOPMENT

A developed Building Occupant Environmental Behaviour (BOEB) model was designed based on the best fitting structural model established through SEM technique; a model that will include three core factors AKB. The developed BOEB model was then completed in several stages based on the literature review and the findings in this research study. The results of survey data analysis were combined with the outcomes of interviews presented in Chapter 4 together with literature review in Chapter 2. These two main data sources formed the components and structure of the developed BOEB model, which covers some more effective factors that can influence occupant environmental behaviour. Finally, the developed BOEB model was validated by experts. The literature review revealed that considerable amounts of time are required in order to develop such models. Such difficulty for model development process was due to the complexity of occupant AKB, together with all the other factors that can influence them directly or indirectly.

3.5.4 BOEB MODEL VALIDATION

After the development of the BOEB model, it was essential to validate the model. This was to:

- Ensure **Effectiveness and applicability** of the BOEB model to address current environmental behaviour of green building occupants.
- Identify **Barriers** to the implementation of the BOEB model.
- Report any further **Recommendations** to improve the BOEB model.

The researcher decided to contact the same building operators who took part in the interviews, as end users of the model, together with some building operators working in Toronto LEED-certified buildings. In addition, two academic researchers were chosen to review and validate the model in Dubai-UAE and Toronto-Canada as the researcher had access to experts in these two regions. The reasons for her choice were first, that the case studies were in the UAE and second, Toronto is a developed city with professionals and researchers working on the similar topics about LEED-certified buildings therefore, the proposed model could be validated by professionals and researchers from both regions to introduce potentially different/ combined perspectives.

Six validation interview sessions were conducted. It should be noted that some of the validators personal information is not included in Table 3.4 to keep them anonymous in line with ethical consideration and promises given to validators. The two exceptions were: i) Dr. Beth Savan, associate professor and researcher at the University of Toronto in Canada who accepted to disclose her name, and ii) Dr. Issam Ezzedine, senior architect at NEB consulting and design firm in Dubai-UAE. Table 3.4 shows the minimum years of experience of the building operators in managing similar buildings and academic researchers in studying similar topics to this research study. Table 3.4 also shows the location of each validator.

Data analysis

The validation process conducted using an interview approach during face to face and Skype meetings. Each validation session was designed to last 60-90 minutes. In addition to the BOs in Dubai-UAE who took part in the interview, some BOs in Toronto-Canada were also targeted.

The interviewees were presented with a summary of the overall research topic that led to the development of the final BOEB model, including the aim and objectives of the research and the preliminary findings. Then, the developed BOEB model was presented to the experts for their review. Finally, the open-ended interview questions were asked. Interviews were recorded after obtaining permission which were analysed later.

The data collection and analysis are systematic and organised under three pre-designed themes, which were decided by the researcher at the start of the validation process to review the effectiveness of and barriers to the developed BOEB model, while receiving recommendations to improve the final model.

Table 3. 4 Background information of the validators

Validators No	Job Title	Location	Years of Experience
1	Building Operator1	Dubai- UAE	9
2	Professional-Dr. Issam	Dubai- UAE	20
3	Building Operator2	Toronto- Canada	12
4	Building Operator3	Toronto- Canada	15
5	Researcher1-Dr. Savan	Toronto- Canada	5
6	Researcher2	Toronto- Canada	5

There will be semi-structured questions under each theme, explained as below:

Theme 1: Effectiveness and applicability of the BOEB model

The semi-structured questions for this theme are as follow:

Is it a logical process?

What do you think of the motivational factors in this model?

How can technology-oriented systems be useful in this model?

What do you think about the interrelationships between the three main factors of Attitude, Knowledge and Behaviour (AKB)?

Do you think such a model should be considered within building management systems as an educational and feedback process?

Theme 2: Barriers to the implementation of the BOEB model

Semi –structured questions for this theme are as follow:

Do you see barriers in application and implication of such model? If yes, what are they and why do you think such barriers are existing?

Theme 3: Recommendations to improve the BOEB model

Semi-structured question for this theme is as follow:

What is your recommendation to overcome the barriers you mentioned in order to improve the effectiveness and applicability of the BOEB model?

CHAPTER 4 - ANALYSIS AND RESULTS

4.1 INTRODUCTION

This Chapter presents the results and key findings of this research study. First the results of the pilot study survey are provided, followed by the main survey results and the outcomes of the interviews with occupants. Finally, the outcomes of the interviews conducted with building operators (BOs) will be presented.

4.2 PILOT STUDY RESULTS

In this section, LEED-certified and conventional building occupant environmental behaviour is compared in order to gain a better understanding of whether occupants residing in green buildings are more environmentally aware and responsible than those in conventional/non-green buildings. Post Occupancy Evaluation (POE) researchers recommend that occupants need to be knowledgeable and educated about their building's technology-oriented systems. However, occupants mostly move into a building with no or very little explanation about how the systems operate or how their use of equipment and/or facilities affects their building's energy usage. For this reason, a pilot study was designed and implemented to discover whether LEED-certified buildings can guide their occupants towards environmentally-friendly behaviour.

Although the sample size is small, the result helped the researcher to decide how to move forward to collect data from a larger research population. A total of fifteen out of seventy one occupants (21.1%) from green/ LEED-certified Trafalgar Central (TC) building accepted the survey invitation, and fifteen out of thirty two occupants (46.8%) from non-green/ conventional Spain cluster building agreed to answer to the following five question:

1. *Do you use any type of heating systems/ equipment during the wintertime?*

Analysis results: In the conventional non-green building, nine occupants out of total of fifteen mentioned that they use heating equipment during the wintertime (Table 4.1). However, In LEED-certified/green building, only one occupant answered 'YES'. The result reveals that the LEED building occupants are comfortable during the wintertime and do not need heating system as much which could be due to good insulation and efficient doors and windows airtightness.

2. *Do you set the thermostat during the summertime?*

Analysis results: In the conventional building eight occupants mentioned that they do decide upon a thermostat setting during the summertime; in the LEED-certified building four of the fifteen participating occupants answered 'YES' (Table 4.1). Although, less occupants in LEED-certified building set thermostat, but there is not enough evidence that whether the other eleven occupants use the system without setting thermostat or they do not need to use the cooling system during the summertime.

3. *Do you set the thermostat during the wintertime?*

Analysis results: Only three occupants out of fifteen in non-green building responded that they set the thermostat in order to remain comfortable during the wintertime in the UAE. In the LEED-certified building, six out of the fifteen occupants replied that they used their thermostat settings during the wintertime (Table 4.1). Those who do not set the thermostat might be using more energy or they might not at all using the air-conditioning systems. Therefore, there is no confirmed finding from the result of this question.

4. *Do you use low energy bulbs?*

Analysis results: In the conventional building, all fifteen occupants responded that they use low energy bulbs which was encouraging. The same situation existed in the LEED-certified building where all fifteen participating occupants revealed that they use low energy bulbs (Table 4.1).

5. *Do you leave your electronic appliances on standby mode?*

Analysis results: Nine occupants from the conventional building answered 'NO' which is two occupants higher than the respondents from the LEED-certified building. This result suggests that LEED-certified occupants are not greener (more energy responsible) by only living in a green/ LEED-certified building (Table 4.1).

The number of 'YES' and 'NO' responses to above five survey questions from both conventional/non-green and LEED-certified/green buildings are shown in Table 4.1. The responses from the total of thirty participants (fifteen in each building) allowed the researcher to gain a better understanding of the occupant behaviour in these two types of buildings. The results from this small sample size did not clearly confirm that LEED-certified building occupants are behaving in a more environmentally-friendly manner than those living in conventional/non-green buildings.

Table 4. 1 LEED-certified and conventional building occupant environmental behaviour comparison

Questions		Conventional building occupants (Spain Cluster)	LEED-certified building occupants (Trafalgar Central)
1. Usage of heating during wintertime	YES	9	1
	NO	6	14
2. Thermostat setting during the summertime	YES	8	4
	NO	7	11
3. Thermostat setting during the wintertime	YES	3	6
	NO	12	9
4. Usage of low energy bulbs	YES	15	15
	NO	0	0
5. Leaving electronic appliances on standby mode	YES	6	8
	NO	9	7

4.2.1 PILOT STUDY CONCLUSION

A total of five questions were asked and the results are presented above. Based on the summary shown in Table 4.1, occupants in LEED-certified buildings are not behaving in a more environmentally-friendly manner than those occupants living in conventional buildings. Results suggest that while the building capabilities, as well as availability and use of personal controls, were higher in the LEED-certified buildings, the behaviour of occupants within LEED-certified buildings is not greener. The pilot study's results are in line with the findings in literature review findings based on the study conducted by Menezes et al. (2012) that occupants of non-green buildings consumed less gas than those occupants residing in green buildings. Therefore, LEED-certification on buildings cannot, on its own, promote environmentally-friendly behaviour of those building occupants. Therefore, the researcher became determined to continue focusing specifically on LEED-certified building occupant environmental behaviour in order to understand occupant environmental behaviour in these green buildings. The LEED-certified buildings are designed to be energy efficient and should be capable of helping their occupants to behave in an environmentally-friendly way. However, it would seem, from the pilot study's results, that LEED-certified building occupants might not be greener and probably more knowledgeable to operate in the most environmentally efficient manner. It is fair, albeit somewhat disappointing, to conclude that the occupants of LEED-certified/green buildings do not demonstrate better eco-centric and environmentally-friendly behaviour than those living in conventional/non-green buildings while this is completely in line with the findings in literature review.

4.3 MAIN OCCUPANT SURVEY AND INTERVIEW RESULTS

4.3.1 SECTION ONE – GENERAL INFORMATION

This section reports the results of responses to the questionnaire containing 31 questions in different sections (Appendix B) conducted with 203 occupants from four LEED-certified buildings in Dubai-UAE, yielding response rate of 76.6% to the survey questions. The following tables show the actual sample results and the weighted results, designed to reflect the population.

As per the results in Table 4.2, the respondents within these buildings who answered the questions are 87.2% male. The gender bias is due to the fact that most properties in the UAE are owned by men, which is why men were available to reply to the survey questions and therefore, there is no cross-tabulation between gender and some of other answers in the following sections. Only 5.4% of the respondents were 50 or older, while 60.6% of them were aged between 31-40.

The majority of the respondents were well educated; one person admitted to having no formal qualifications and only 14.8% were at a high school diploma level. As the majority of the occupants (84.7%) are with higher education, there is no cross-tabulation between this factor and the rest of their answers.

Table 4. 2 Gender, age and education

		Frequency (n=203)	Percentage (%)
Gender	Male	177	87.2
	Female	26	12.8
Age	<=30	35	17.2
	31-40	123	60.6
	41-50	34	16.7
	>50	11	5.4
Education	No qualification	1	0.5
	High school	30	14.8
	Bachelor	118	58.1
	Master or higher	54	26.6

Table 4. 3 Occupation status, Years of occupation & number of occupants

		Frequency (n=203)	Percentage (%)
Occupation status	Tenant	184	90.6
	Owner	19	9.4
Years of occupation	<1	139	68.5
	1-3	48	23.6
	>3	16	7.9
Number of occupants	1	4	2.0
	2	25	12.3
	3	60	29.6
	4	68	33.5
	>=5	46	22.7

Table 4.3 shows the difference between the rental and owner sector is significant, 90.6% are renters and hence do not own their property. The occupants are mostly new occupants, and this is due to their new constructed LEED-certified buildings. LEED-certified buildings are a relatively new concept, and this is reflected in the date of occupation across all case studies. By the very nature of property developed with the aid of LEED- certification, these types of

buildings are quite new; for example, some have been occupied for less than a full year. Nonetheless, the short period of occupancy is recognised as a potential problem for this research. Firstly, without a full year involving all seasons, it is difficult to determine all the flaws; however, there are mainly two seasons in the UAE; hot in summertime and warm and cool in wintertime.

Table 4.3 shows that there are mostly three to five occupants per apartment. 22.7% have five or more residents, 33.5% accommodate four persons, 29.6% have three tenants and 12.3% of them are two persons living in one flat. There is only 2% as a single occupant.

4.3.2 SECTION TWO – ATTITUDES TOWARDS ENVIRONMENTAL ISSUES

In this section both owners and renters were asked about different patterns of building occupant environmental attitudes and awareness. The tenants were asked about their views regarding the following issues: a) climate change, b) impact of energy use on the environment, c) current lifestyle related to the environment or in other words current pro-environmental lifestyle, d) environmentally-friendly lifestyle comparison, e) level of importance for different parameters while choosing the home, f) level of awareness about green buildings and finally g) awareness of the term LEED-certified building while choosing the home. Further investigation was done through interview with ten building occupants and five operators.

a. Views on climate change

Table 4.4 shows occupant views on climate change, 34.5% believe that there is a major threat to the world from climate change and 44.3% claimed that there is some threat; the message from government and scientists appears to have been understood. 6.4% of occupants are of the opinion that the threat is little, while 11.3% believe there is no evidence for climate change at all and 3.4% apparently did not know about the phenomenon.

This view through analysis by age in Table 4.5 shows that those in the 41-50 age group are significantly more likely to see climate change as a major threat (41.2%), while both younger groups still find it as a major or some threat. The findings suggest that they are receptive to the climate change message.

Those aged over 50 appear significantly less interested, in principle, than other age groups and 27.3% believe there is no evidence for climate change. As discussed, the majority are educated male (more than 80%) and therefore, there is no cross-tabulation between those factors and the other occupant answers.

Table 4. 4 Views on climate change

	Frequency (n)	Percentage (%)
Climate change is a major threat to the world	70	34.5
There is some threat to the world from climate change	90	44.3
There is little threat to the world from climate change	13	6.4
There is no evidence for climate change	23	11.3
Don't know	7	3.4
Total	203	100.0

Some of the occupants do not believe in climate change, as confirmed by a representative quote given below:

"There is no evidence about climate change, and this has nothing to do with my age, it is because some years it gets colder and sometimes extremely hot, so there is no consistent increase to give such impression." Occupant 3 in TC.

The majority believed in climate change; this is typified by the following comment:

"I read every day about climate change and global warming and this is based on science and findings from all around the world, so nobody can deny or ignore it." Occupant 9 in HDS SS II.

Table 4. 5 Age and views on climate change cross-tabulation

		View on climate change				
		Climate change is a major threat to the world	There is some threat to the world from climate change	There is little threat to the world from climate change	There is no evidence for climate change	Don’t know
Age	30 or under	31.4%	42.9%	14.3%	11.4%	
	31-40	35.0%	49.6%	3.3%	8.9%	3.3%
	41-50	41.2%	35.3%	5.9%	14.7%	2.9%
	50 or greater	18.2%	18.2%	18.2%	27.3%	18.2%

b. Belief about the impact of energy use on the environment

Table 4.6 shows the participants overall views of the impact of energy use on the environment. 60.1% believe that energy use has a ‘major’ impact on the environment and climate change. 28.1% agree with a ‘limited’ impact while only 11.9% chose either ‘no impact’ or ‘don’t know’.

<u>Table 4. 6 Impact of energy use on the environment</u>

	Frequency (n)	Percentage (%)
Energy use in homes has a major impact on the environment and climate change	122	60.1
Energy use in homes has a limited impact on the environment and climate change	57	28.1
Energy use in homes has no impact on the environment and climate change	20	9.9
Don't know	4	2.0
Total	203	100.0

The majority confirmed that there is an impact of energy use on global warming, as seen in the following quote:

"I think people who don't think there's impact of energy use on global warming are wrong, how do they deny this? We are throwing tons of carbon monoxide into the environment every year. How could this not make a negative impact, it does not just like drift off into outer space." Occupant 9 in HDS SS II.

c. Current lifestyle related to the environment

Table 4.7 shows the results of examining the current lifestyles of the occupants in relationship to the environment. Only 10.3% of them are 'happy' with how they are conducting their lives; 50.7% of them want to 'do a bit more' and 37.9% are willing to 'do a lot more'. The finding that the majority is willing to 'do more' is a very promising one, as it suggests that people are ready to access education on energy conservation.

Table 4. 7 Feelings about current lifestyle related to the environment

	Frequency (n)	Percentage (%)
I'm happy with what I do at the moment	21	10.3
I'd like to do a bit more to help the environment	103	50.7
I'd like to do a lot more to help the environment	77	37.9
Don't know	2	1.0
Total	203	100.0

d. Environmentally-friendly lifestyle changes and comparison between now and 4 years ago

This question deals with concerns about the threat of climate change and the scarcity of non-renewable resources, with particular focus on the extent occupants are adapting their lifestyles to reduce the threat, when compared to 4 years ago.

Despite these concerns, only 60.6% of occupants think they have done more than they were doing 4 years ago to be environmentally-friendly. Over one quarter of the occupants have carried on in the same way and 15 of the 203 indicated that they 'don't know' if they have improved their lifestyle to become more environmentally-friendly (Table 4.8).

Some respondents do not go further either because it is difficult for them to see the impact on the planet in the wider context, or because the effort of the individual is considered ineffectual or of no consequence.

"You hear about globalisation and some countries are happily polluting the planet. What little we do; what impact are we having." Occupant 3 in TC.

"I don't think that the environment is as high on some people's priorities as perhaps the media suggests it should be, but money, yes, it is, definitely." Occupant 5 in PR I.

"I try to do something, but I am not an environmentalist." Occupant 10 in HDS SS II.

Most occupants believed that they needed to change their lifestyles, and this is typified by the following statements:

"*I think it's clear that we have a limited amount of resources on earth and they will disappear at some point of time. So, I think renewable energy and technologies are critical more than what we do."* Occupant 1 in TC.

"I have done more because after residing in this building which was called LEED-certified, I started to learn about it, so I know more today, and I do more too." Occupant 9 in HDS SS II.

Table 4. 8 Environmentally-friendly lifestyle comparison between now and 4 years ago

	Frequency (n)	Percentage (%)
I do more	123	60.6
I do same	55	27.1
I do less	10	4.9
Don't know	15	7.4
Total	203	100.0

Findings from interviews in this part of the research show that people are willing to change their lifestyles to help the environment but only up to the point where it starts to have an adverse effect on their lives, it costs money, or the disadvantages outweigh the benefits. Results in section 3 of this Chapter (Table 4.22) show that, where savings can be quantified, or financial incentives provided, such as cash back, then there appears to be a willingness by 88% of occupants to undertake action to reduce energy consumption; in the other words 'to become environmentally-friendly by changing their lifestyles'.

Results from the interviews in this section have shown that majority of those living in green buildings are more likely to be taking steps to reduce their carbon footprint if they are educated about the environmental aim of such buildings therefore, sharing information (**Knowledge**) with them is essential.

e. Level of importance for different factors while choosing the home

In this question, the respondents were asked about different parameters that influenced their decision-making process in choosing a home. The respondents had to rank them in order from 1 to 6, with 1 being the most important factor and 6 the least important.

Occupants, both owners and renters, were first asked to describe the key factors that they would or did consider. 82.8% of the respondents mentioned that 'location' is the most important factor for them, while 80.8% chose 'energy efficiency features' as the sixth, or least, important factor. This shows that a building's environmental sustainability has a very low priority, despite their answers to the earlier questions.

Table 4.9 shows the percentages for each factor and at the end some statistical analysis was carried out in Tables 4.10 and 4.11 to compare means of all six factors while their levels of importance are measured.

Table 4.10 show mean comparisons between the different factors level of importance. While most factors have significant differences, there is a very small difference between external environment (3.90) and cost (3.74). Table 4.10 shows that although upper values are very close (external environment = 3.97 & cost = 3.93), the difference between lower values is greater (external environment = 3.82 & cost = 3.55). The result will keep 'cost' at a higher importance level than 'external environment'.

These results suggest that 'energy efficiency features' are not important, as in Table 4.10. In Table 4.11 the bigger the value of 'mean', 'mean difference' and 'standard deviation' is, the less important that factor is considered to be. The results within section 4 of this report show the level of satisfaction with energy bills. Only 3% are 'strongly satisfied' and 23.2% are 'satisfied'; the majority of occupants are either 'neutral' or 'dissatisfied' with their energy bill totals. They appear not to care seriously about 'energy efficiency features'; the very important factors which can facilitate their energy cost reduction.

Table 4. 9 Ranking votes for occupant preferences

	Ranking Votes						**Ranking**
	1st	2nd	3rd	4th	5th	6th	
Location	168	33	2	0	0	0	**1**
External environment	0	3	34	148	17	1	**4**
Size of the home	17	153	28	4	0	1	**2**
Energy efficiency features	0	0	5	8	26	164	**6**
Costs (to rent or buy)	17	14	68	19	76	9	**3**
Style of the building	0	1	67	23	84	28	**5**

Table 4. 10 One-sample statistics compare means

	N	Mean	Std. Deviation	Std. Error Mean
Location	203	1.18	.412	.029
External environment	203	3.90	.567	.040
Size of the home	203	2.11	.607	.043
Energy efficiency features	203	5.72	.656	.046
Cost (to rent or buy)	203	3.74	1.363	.096
Style of the building	203	4.35	1.095	.077

During the interviews, most of the occupants started to think about their high energy bills:

"*Energy bills have gone up dramatically. Doing something can actually have an impact so people are paying more attention."* Occupant 5 in PR I.

Some of the occupants also did not know whether their appliances were 'Energy Star' rated or energy efficient.

"I was not aware of energy efficient features, so this was not the attraction to me to choose this home." Occupant 7 in PR II.

Based on Table 4.9 and mean comparisons in Tables 4.10 and 4.11, key factors in order of importance are shown in Figure 4.1.

Table 4. 11 One-sample test confidence intervals of the difference

	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Location	40.904	202	.000	1.182	1.13	1.24
External environment	98.000	202	.000	3.897	3.82	3.97
Size of the home	49.615	202	.000	2.113	2.03	2.20
Energy efficiency features	124.169	202	.000	5.719	5.63	5.81
Cost (in rent or to buy)	39.089	202	.000	3.739	3.55	3.93
Style of the building	56.602	202	.000	4.350	4.20	4.50

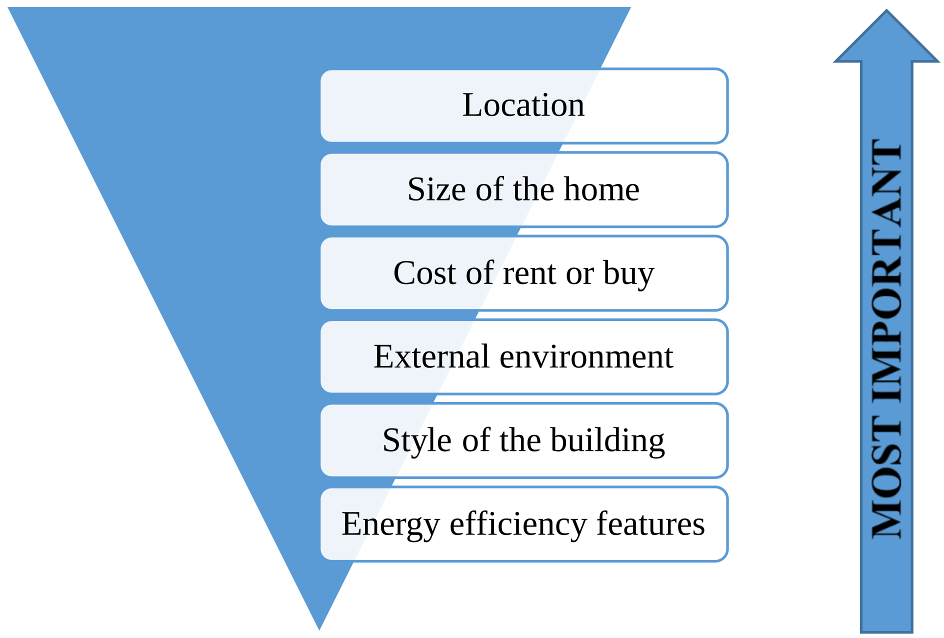

Figure 4. 1 Level of importance for different factors while choosing a home

f. Attitude and belief about green buildings

Table 4.12 shows that the majority of occupants (72.4%) were familiar with the term ‘sustainable /green building’ and believed in it; however, 22.2% had not believed in the term and 5.4% answered ‘don’t know’. Some representative quotes are given below:

“It’s a major benefit to live in a green building and I happen to feel very strongly about recycling and conservation and sustainability, so it fits my mindset, but if there are clauses in it I’m not familiar with what I would like to learn.” Occupant 9 in HDS SS II.

“I know something about green building but don’t know all the details exactly.” Occupant 10 in HDS SS II.

Occupants mentioned they are familiar with the term ‘sustainable /green building’ despite not believing and identifying certain deficiencies and awareness about its performance details.

<u>Table 4. 12 Attitude and belief about the term 'sustainable/green building'</u>

	Frequency (n)	Percentage (%)
Yes	147	72.4
No	45	22.2
Don't know	11	5.4
Total	203	100.0

g. Considering the term LEED-certified while choosing the home

Based on Table 4.13, approximately half of the occupants (49.8%) considered and believed in the term 'green/LEED-certified building' but it had no effect on their choice of accommodation as shown in Figure 4.1 that 'energy efficiency features' were their sixth priority. Results from the interviews indicated that the occupant level of awareness and education about LEED-certification can increase the level of effect on their choice of a home. Several quotes confirmed this perspective:

"I remember that I saw bunch of numbers and description, but it had no major effect on my decision as other factors such as location of the building, size of the home and rental price was more important to me." Occupant 5 in PR I.

"I noticed it and I think it is something to be proud of to live in a building that actually has awards and certification." Occupant 9 in HDS SS II.

"*That was not initially considered, was not a high item on my list initially. It was not something that we were specifically looking for, but we were aware that this building was green/ LEED-certified."* Occupant 1 in TC.

"As an architect, yes, I understand what it implies, and it affected my decision… It's a lot of money and it's a lot of effort to be LEED-certified." Occupant 2 (Architect) in TC.

Table 4. 13 Considering the term 'LEED-certified/green building' while choosing the home

	Frequency (n)	Percentage (%)
Considered it, understood it and it influenced my decision	49	24.1
Considered it and understood it	101	49.8
Considered it but didn't understand it	12	5.9
Didn't consider it	41	20.2
Total	203	100.0

4.3.3 SECTION THREE – ENVIRONMENTAL BEHAVIOUR

This section presents the analysis of the building occupant behaviour on recycling and environmental activities.

a. Availability of reserved parking lot for hybrid cars

Based on the results from Table 4.14, 67.0% of respondents knew about the existence of reserved parking while 34% mentioned 'no' or 'don't know'. The findings from interviews indicated the low usage and/or lack of information about such parking for hybrid cars, as indicated in the following representative comments:

"There are such parking and they are closer to the entrance door to encourage occupants to use hybrid cars, but all I see there are only higher model cars which are parked in those spaces." Occupant 3 in TC.

"I've never seen hybrid cars, so I don't know if there are dedicated spaces." Occupant 10 in HDS SS II.

<u>Table 4. 14 Occupant awareness about availability of reserved parking lot for hybrid cars</u>

	Frequency (n)	Percentage (%)
Yes	136	67.0
No	21	10.3
Don't know	46	22.7
Total	203	100.0

b. Availability of the recycle bins in the building

Almost half of the occupants were aware of availability of the recycle bins but still 36.5% did not know about such a facility (Table 4.15). The building management has a recycling programme that provides the recycling bins on every floor, yet still some occupants were not informed of this option.

<u>Table 4. 15 Occupant awareness about the availability of the recycle bin</u>

	Frequency (n)	Percentage (%)
Yes	110	54.2
No	19	9.4
Don't know	74	36.5
Total	203	100.0

c. Occupant behaviour toward recycling strategies

The occupant behaviour towards recycling is been reviewed. Table 4.16 shows the percentages for each activity.

Table 4. 16 Recycling

	Constantly	Frequently	Occasionally	Never	**Ranking**
Paper	45	54	32	72	**1**
Plastic	30	39	47	87	**2**
Glass	25	40	51	87	**3**
Metal	20	36	51	96	**5**
Carton boxes	22	36	67	78	**4**

In Figure 4.2, '1' stands for 'constantly' and '4' for 'Never', the most constant recycling activity continues to be recycling papers and occupants give the least attention to recycling metal pieces. However, based on results in Table 4.15, 54.2% of occupants were aware of the recycle bin availability in the building, while 36.5% of them did not know about it. This not-knowing shows the need for immediate action in awareness-raising **(Knowledge)** for occupants about the importance of recycling materials in order to help the environment. Occupants are not active in pursuing sustainable lifestyles as the findings showed that in average 80 out of 203 participants never recycled any materials. However, some of the respondents were extremely positive about the value of recycling, as can be seen in the following comments:

"Well, I've been doing recycling for years, I mean, because when we were younger, you know, we used to try to make money all the time, so we would go collecting glass bottles and cans, and take them to the little shop where they give you a little cash for it. Therefore, I have been doing stuff like that, so that is nothing new. I am still doing materials recycling constantly." Occupant 4 in PR II.

"I am religious about recycling because I hate waste. I won't waste anything, my recycling is way bigger than my trash, which I think is good, I recycle everywhere." Occupant 9 in HDS SS II.

Some also believed that recycling helps the environment:

"It's a conscious and kind thing to do to the environment, so I recycle everything." Occupant 2 (Architect) in TC.

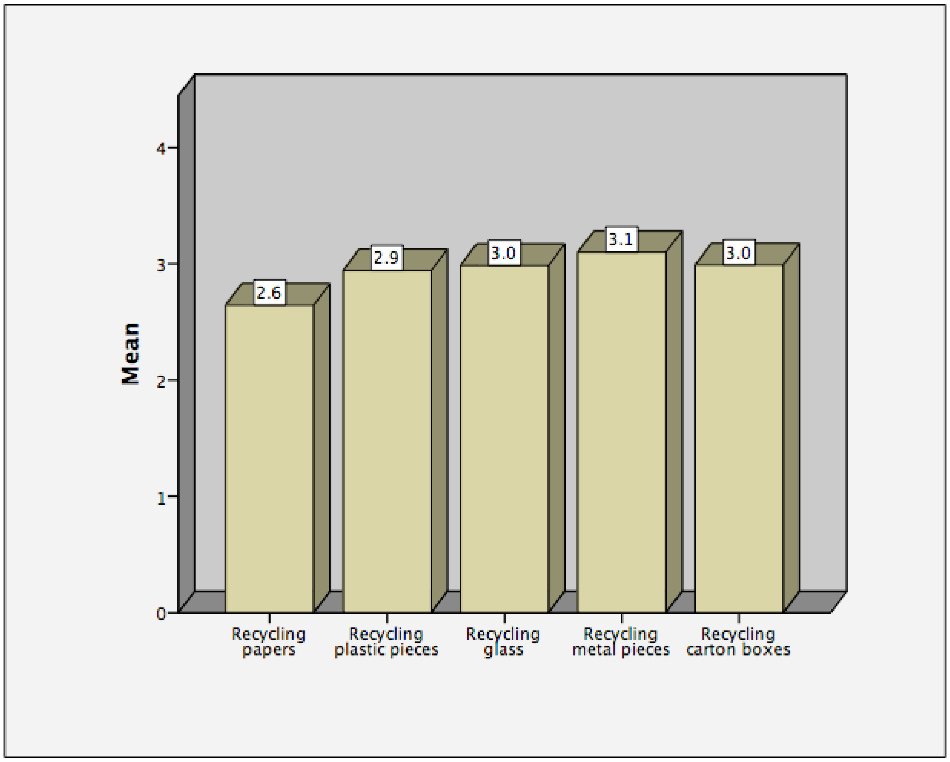

Figure 4. 2 Materials recycling (1=Constantly, 2=Frequently, 3=Occasionally & 4=Never)

However, even though the recycling programme appeared to be well set up in the building, one of the occupants mentioned that they did not recycle:

"Because the building itself does not. I do not know if they recycle but like in the trash room, there is just one chute and then one canister for papers, but it does not sort plastics or metal, or I don't know if they do. If the building made it more convenient, we would do it." Occupant 10 in HDS SS II.

"Well, about recycling, I don't know, because hearing people talk about it so much." Occupant 3 in TC.

All of the above statements are showing that raising awareness **(Knowledge)** and creating socio-cultural environment **(Motivation A)** can motivate occupants to behave more environmentally-friendly.

d. Water-saving

Table 4.17 shows 25.6% of the occupants claimed to constantly use their washing machines ‘economically’, 57.6% ‘frequently’ and 13.8% ‘occasionally’, with only 3% claiming ‘never’.

The constant usage of dishwashers is the same as washing machines; however, almost half of the occupants (47.8%) never used their dishwasher economically, even though they had one inside their homes.

Table 4.17 shows the results of constantly or frequently using less water in toilets by the majority of the occupants. The argument against efficiency in use was further supported when the research confirmed that 49.8% of the respondents ‘constantly’ or ‘frequently’ pressed both buttons, while 29.1% did so ‘occasionally’ and 21.2% of respondents claimed ‘never’.

Table 4.17 shows half of the occupants ‘frequently’ took showers instead of baths and 25.1% did so ‘constantly’. Only 2.5% claimed that they ‘never’ take a shower and so they use more water to bathe.

The main step taken to reduce water usage in the home continues to be turning off the tap when brushing teeth, as reported by 62.6% of the occupants.

Some occupants mentioned that they use the washing machine and the dishwasher economically. The researcher asked them to explain what they mean by ‘using them economically’. It was explained:

“I gather clothes and dishes and never turn on the machines until they are full and make sure to put them on the light wash.” Occupant 4 in PR I.

“I use them once a week and hand-wash some clothes and dishes which is a bit time-consuming but reduces my energy bills.” Occupant 5 in PR I.

“I try to use everything economically, because energy bills are very high, for example I don’t use dishwasher at all, but still I should use the minimum such as washing machine that I need.” Occupant 9 in HDS SS II.

Even though the washing machine is a major component in modern life, it seems the occupants started to have 'constant' or 'frequent' economical usage of it. This trend was investigated and revealed that the deciding factor regarding limited washing machine usage was the high cost of water and electricity in the UAE.

Table 4. 17 Water-saving

	Constantly	Frequently	Occasionally	Never
Using the washing machine economically	52	117	28	6
Using the dishwasher economically	55	41	10	97
Using less water in the toilets	57	95	42	9
Pressing both buttons on the WC flush	19	82	59	43
Taking a shower instead of bath	51	111	36	5
Turning tap off when brushing teeth	127	37	31	8

Those occupants who constantly press both buttons on the WC flush confirmed that they did not know the reason of having a dual flush option:

"I always press both buttons because I don't know which is for what and I think I should press both of them." Occupant 7 in PR II.

These examples in this section again cite lack of education, training, and dissemination of information **(Knowledge)** as a major problem:

"My child said, 'You need to turn the water off while you're brushing your teeth.' I answered, 'Why?' She said, 'Because you can save the energy, you save energy, you're saving water,' and I said, 'OK.' Right now, whenever I brush my teeth, I turn the water off, I take shower instead of bath, so I learnt from her." Occupant 10 in HDS SS II.

"I prefer bathing to taking a shower just because I want to spend more time and relax in the bathroom and never thought about the amount of water being used, but I think filling my bathtub and taking shower consume same amount of water, I don't know." Occupant 3 in TC.

Even the small percentage who never take a shower, instead preferring to bathe, might change their habits if they became aware of the amount of water and of course money they can save.

Some occupants were not aware of water conservation fixtures:

"Nobody informed us when we took up residence here but probably, well I don't know, I am trying to think, maybe the shower fixture heads are water conserving, they might be, we take care to conserve water, but I don't know other than the water shower heads, I don't know if there are any features. Low-flush toilets, maybe, my husband or daughter probably know better." Occupant 10 in HDS SS II.

The most common action is to turn the tap off when brushing teeth, while the second most constant action is to use the washing machine economically; the latter point needing further investigation in order to clarify what exactly is meant by 'economically' (Figure 4.3).

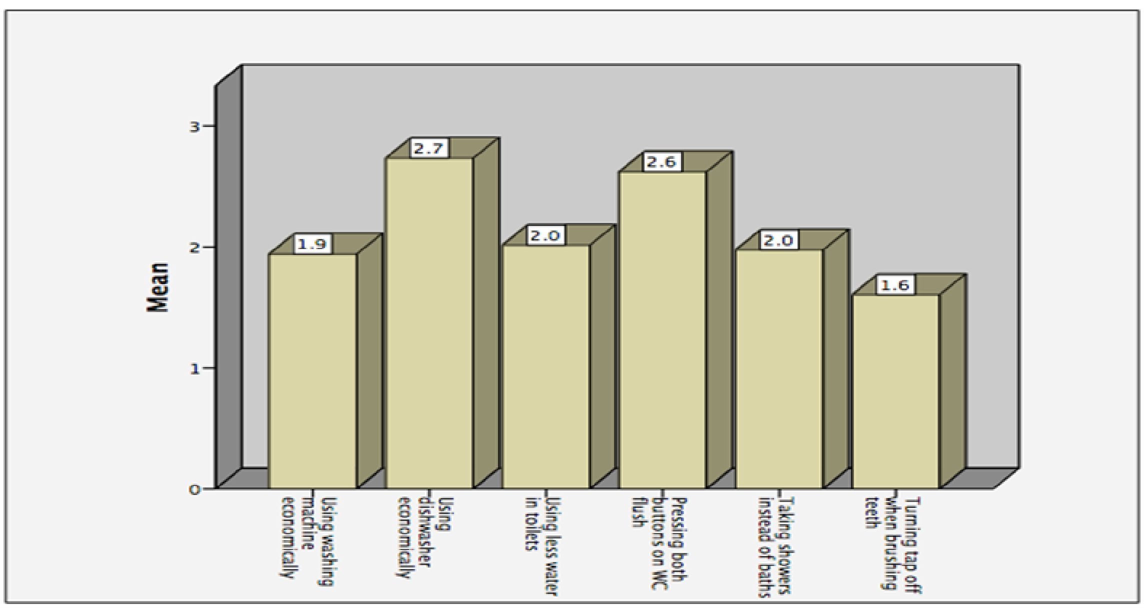

Figure 4. 3 Reducing water consumption (1=Constantly, 2=Frequently, 3=Occasionally & 4=Never)

e. Energy-saving

Table (4.18) shows occupant behaviour through different energy saving approaches. Based on the mean analysis presented in Figure 4.3, the most common actions taken to reduce energy use are firstly turning off the lights if they are not needed, then keeping the AC off when windows are open and, after that, setting the thermostat for appropriate air conditioning.

"I leave some lights on even when I am sleeping because I don't like darkness" Occupant 6 in PR I.

"I always leave my appliances on standby mode, turn lights off if they are not needed and use energy labelled appliances even if they are more expensive." Occupant 9 in HDS SS II.

"Most energy labelled appliances and LED bulbs are more expensive and that prevents me sometimes from buying them. How much, and when, am I going to be paid back?" Occupant 5 in PR I.

"I don't know very well about such appliances, nobody in shops or inside the building informed me about the benefits of them." Occupant 7 in PR II.

The cost of energy efficient appliances and bulbs seems to be the main concern for some occupants, who are aware and never go for these options, but others are not aware of their existence.

Some occupants did not know how to use their home's thermostat due to lack of guide **(Knowledge)**, while some expressed their satisfaction with their thermostat setting:

"The thermostat is supposed to be economical, but I don't think anybody figured out how to work with it. It is a little difficult and we need to be trained. I think our bills were pretty high until you figured out what setting to put it on, there are few options." Occupant 1 in TC.

"Since we've moved here, the thermostat makes it really easy to conserve energy, so we use that." Occupant 5 in PR I.

Results from the interviews showed those who open their windows 'constantly' leave their AC on at the same time. From their perspective the main reason for opening windows appeared to be for air ventilation:

"I open windows in the summer and leave AC on to circulate air inside my home." Occupant 10 in HDS SS II.

Table 4. 18 Energy-saving

	Constantly	Frequently	Occasionally	Never
Leaving appliances on standby mode	42	37	57	67
Turning off lights when they are not needed	135	63	3	2
Using low energy light bulbs	75	102	25	1
Using low energy labelled appliances	52	91	58	2
Setting the thermostat for air conditioning	88	81	23	11
Keeping AC off when windows are open	135	40	17	11
Keeping windows open during the summer	26	33	66	78
Keeping windows open during winter	44	92	44	23
Closing windows shades/ blinds	64	66	59	14
Controlling doors/ windows airtightness	63	75	45	20

"I just like to keep windows open in the summertime and wintertime, because fresh air is moving." Occupant 3 in TC.

Occupants should not need to open windows, as much due to the proper ventilation system within HVAC and therefore, doing so is likely to have an adverse effect by significantly increasing the energy usage. Such occupants behave in the way they do because of their lack of awareness and education **(Knowledge)**:

"For the past month in the wintertime, I haven't used any heating and cooling just the temperature has been moderate, and I can open windows if it's too hot. I can close the windows and the sun heats up my apartment if it is too cold. So, I think there's a couple of months each year when I don't use any heating or cooling and just open the window whenever I need to, but during summertime I never open the windows, I know some people who use AC constantly, even during winter days." Occupant 9 in HDS SS II.

The findings confirmed that different behaviours regarding AC usage, together with window opening, relate to occupant comfort level differences and preferences, which are decided by the temperature both outside and inside their homes.

Dealing with an 'air tightness' strategy is simple and cheap. It is not easy to determine the minimum level of air leakage that is necessary for buildings. Analysis in Table 4.18 show that the majority of occupants constantly and frequently control their windows and doors airtightness, and nearly 10% of them were not aware of such a strategy. However, further analysis showed that even those who specified 'constantly' were not aware of conducting technical airtightness control and they misunderstood the term 'airtightness'.

"I always check if humidity and dust is coming through my door and windows, I think that is airtightness, if there is any technical approach then I really don't know about it." Occupant 1 in TC.

"I don't know the meaning of airtightness and if it is something important then our building manager should inform us." Occupant 10 in HDS SS II.

By comparing means (Figure 4.4) most occupants never left their appliances on standby mode, yet they kept windows open during the summertime.

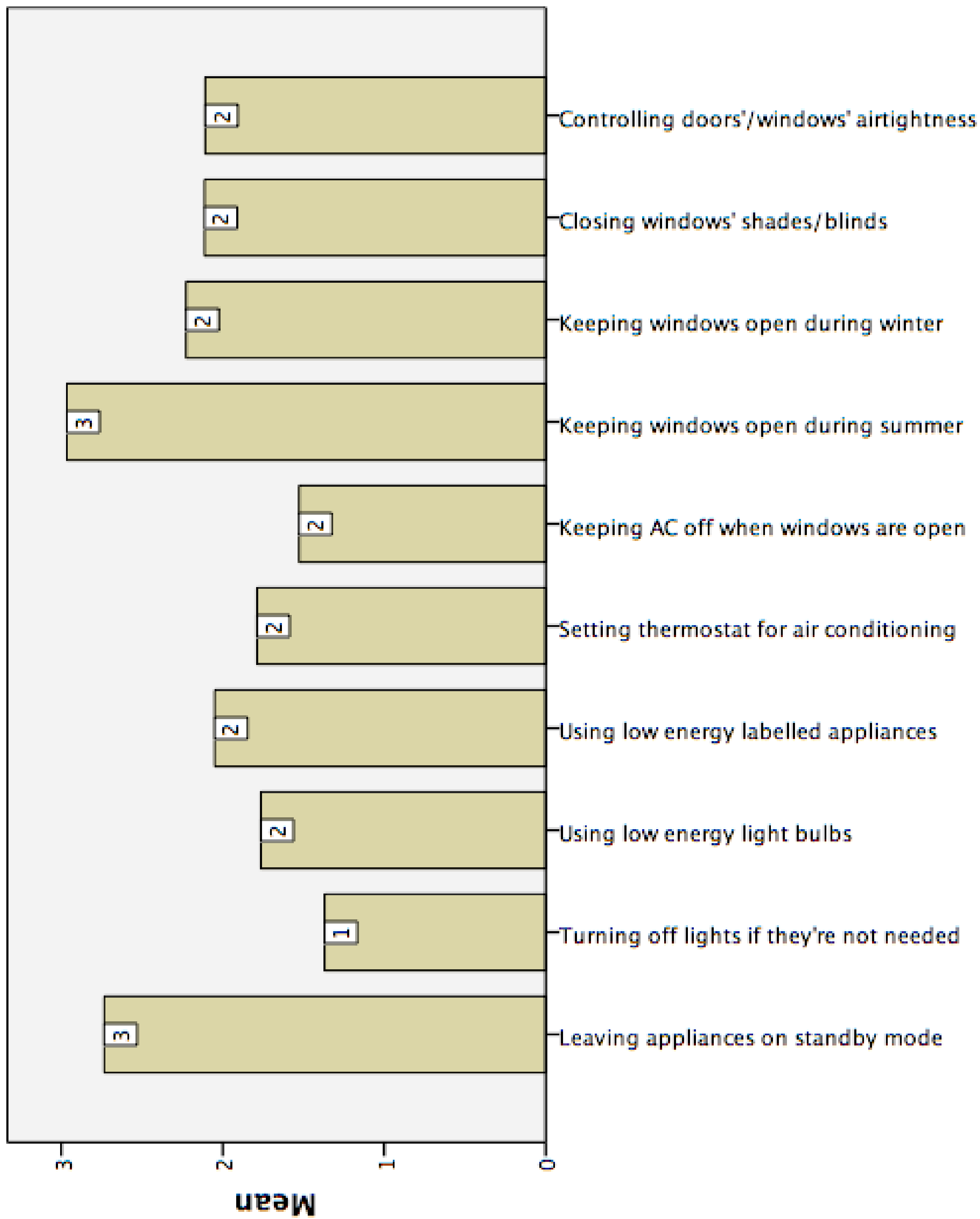

Figure 4. 4 Reducing energy consumption (1=Constantly, 2=Frequently, 3=Occasionally, 4=Never)

f. Types of artificial lighting fixtures

Results in Table 4.19 indicate that 53.2% of the occupants know all lights are fitted with energy saving bulbs and 37.9% mentioned the existence of both types of bulbs (ESL/LED).

Table 4. 19 Types of fixed artificial lights

	Frequency (n)	Percentage (%)
All lights are fitted with energy saving ESL/LED bulbs	108	53.2
Some lights are fitted with ESL/LED bulbs and some with traditional normal bulbs	77	37.9
All lights are fitted with traditional normal bulbs	14	6.9
Don't know	4	2.0
Total	203	100.0

Some interviewed occupants mentioned:

"*I am sure about having some ESL/LED bulbs fitted and some traditional and for those which are traditional changing them to ESL/LED bulbs might not give me a sufficient amount of artificial lights."* Occupant 2 (Architect) in TC.

"I don't know exactly the difference between traditional and energy saving bulbs, but they all look like traditional ones, so I chose the answer all-traditional." Occupant 7 in PR II.

The last answer from the interviewed occupant suggested that the building manager should provide brochures or place information on announcement boards about bulb differences and their benefits with regards to energy saving **(Knowledge).**

g. Artificial lighting and AC daily usage

Table 4.20 shows 67.5% of the occupants use artificial lighting only 1-6 hours out of every 24 hours. There are only 2 occupants who are using lighting 19-24 hours a day. Those are the occupants who expressed concerns about darkness in previous interviews cited above (*e. energy saving, p.87).* Seasonal variations for the day's length in the UAE are not more than 3 hours, while the average day's length between sunrise and sunset in winter is 10:40 hours and in summer is 13:40 hours. As a result of these variations the hours of consumption are measured for every 6 hours, to help gain the idea of average consumption in a year.

During the interview, some occupants were asked about the reasons for their reduced artificial lighting usage:

"I am mostly outside and when come home I need only about 2 hours to get ready to go to the bed." Occupant 1 in TC.

"I spend less time in my home and even if I am inside the natural light during daytime in sufficient, so I only use few lights after sunset." Occupant 2 (Architect) in TC.

When comparing the results in Table 4.20, occupants left their AC on during summer days between 7 and 18 hours while in a winter day their consumption drop dramatically. 53.2% of the occupants did not use AC at all during the cold winter days and 36.5% only used between 1-6 hours. This significant difference is due to the huge differences between temperature and humidity levels in the summertime and wintertime in the UAE.

Table 4. 20 Hourly usages of artificial lighting and AC

		Frequency (n=203)	Percentage (%)
Hourly use of artificial lighting in a day	1-6 hours	137	67.5
	7-12 hours	58	28.6
	13-18 hours	6	3.0
	19-24 hours	2	1.0
Hourly working of AC in a summer day	Don't use AC at all	6	3.0
	1-6 hours	33	16.3
	7-12 hours	69	34.0
	13-18 hours	68	33.5
	19-24 hours	27	13.3
Hourly working of AC in a winter day	Don't use AC at all	108	53.2
	1-6 hours	74	36.5
	7-12 hours	9	4.4
	13-18 hours	8	3.9
	19-24 hours	4	2.0

h. Walking, cycling, and using public transportation

Walking and cycling are not very common activities during summer in the UAE due to the hot and arid climate. After reviewing the results in Table 4.21, the reasons for never walking (19.7%) and never using public transport (10.3%) were raised during the interviews. The majority of the respondents showed negative attitudes towards constantly using alternative transportation, such as walking and public transportation.

"I am very busy, and I really need to use my car at work and usually go to the supermarket while driving on my way home." Occupant 4 in PR I.

"I wish I could use public transportation but the access to my work is very difficult without a car, because there is no bus or train from the subway and taxi is very expensive and sometimes difficult to get on time." Occupant 9 in HDS SS II.

Table 4. 21 Walking, cycling, and using public transportation

	Constantly	Frequently	Occasionally	Never
Walking or cycling to the work/ supermarket	34	59	70	40
Using public transportation	34	49	99	21

i. encouragement to reduce water and electricity consumption

Occupants were asked about different encouragements for reducing water and electricity consumption such as 'environmental and climate change concerns' and 'reduced energy bills' plus 'receiving cash-back on savings' **(Motivation B).**

Based on the findings in section 2, energy-efficient features are not a main attraction when first considering the home, in fact, they were ranked last out of six choices. However, those features added to the home's appeal when savings on energy bills and cash-back on savings were considered. Reducing energy bills in Table 4.22 is seen as the bigger value where 37.4% chose this answer; with no significant difference, they chose both answers which means 51.2% of respondents have environmental and economic concerns.

Based on the reactions to the question given during the interview, a simple payback period of up to five years, together with receiving cash back on energy savings, are likely to be considered. Those occupants in the survey who say they would be encouraged by 'energy bills reduction and cash back prizes' (**Motivation B**) gave the length of time to recoup any outlay as their main reason for not doing so.

"I don't know how long I will live in Dubai, but I would rather have a shorter time period for example 5 years or receive cash-back on my energy bills reduction if my consumption is below some specific amount." Occupant 5 in PR I.

Table 4. 22 Encouragement to reduce water and electricity consumption

	Frequency (n)	Percentage (%)
Environmental and climate change concerns	19	9
Energy bills reduction and receiving cashback on saving	76	37
Both of the above	104	51
None of the above	2	1
Don't know	2	1
Total	203	100

Occupant willingness to reduce energy consumption to help the environment declines with age, again contrary to the increase in the importance of energy bills revealed in this study. Those at the earlier age are more encouraged to reduce water and electricity consumption for both environmental concerns and energy bill reduction and receiving cash-back rewards.

Cross tabulation in Table 4.5 between occupant age and view on climate change threats confirm their willingness to reduce energy, however their belief has not been translated fully into their environmentally-friendly behaviour due to findings in section 4.3.3.

4.3.4 SECTION FOUR – OCCUPANT SATISFACTION LEVEL

This section presents results of the survey responses where occupants were provided with several criteria relating to comfort and satisfaction level. The following sections explain the results presented in Table 4.23:

Indoor air quality (IAQ)

The level of satisfaction with indoor air quality is high: 73.9% of respondents are strongly satisfied or satisfied.

Thermal comfort (TC)

Occupant satisfaction with thermal comfort is also high, with 17.2% of the occupants being strongly satisfied and 67% satisfied.

Acoustic comfort (AC)

For the level of satisfaction with acoustic comfort, 58.1% of occupants are strongly satisfied or satisfied for not having noise from neighbours, the HVAC system or from outside. Nearly half of the occupants suffered from the outside noise and they are either neutral or unsatisfied. Further investigation showed that some have noise from outside.

"I can hear little noise from some neighbours." Occupant 10 in HDS SS II.

"There is no noise from HVAC but some neighbours are noisy inside corridors, but I can't hear them when they are inside their homes." Occupant 1 in TC.

"No Noise." Occupant 5 in PR I.

Considering the level of comfort, the reason for any dissatisfaction reveals some occupant poor social behaviour rather than issues with the building itself in terms of sound insulation.

Natural lighting comfort (NLC)

Analysis shows that the level of satisfaction with natural lighting comfort is high (80.3%).

Artificial lighting comfort (ALC)

72.9% of the occupants are satisfied with the amount of artificial lights in their homes.

Building cleanliness (BC)

Just over half of the occupants (55.6%) are neutral or unsatisfied with their building's cleanliness.

"I think building staff should clean the corridors and parking in a better way." Occupant 10 in HDS SS II.

"There is always some trash inside the parking area." Occupant 4 in PR I.

Maintenance and operation (M&O)

Almost half of the building occupants are satisfied with maintenance and operation; however, 36.5% are 'neutral' which does not show whether they are satisfied or unsatisfied. Interview results show even the unsatisfied occupants did not have clear reasons for their choice, while 58.6% of them believe they understand how to operate the technological features of their homes and they are satisfied. The following statements revealed that there is lack of guide and information provided to occupants **(Knowledge).**

"I have doubts about whether buildings features are working properly." Occupant 7 in PR II.

"The information provided to me at occupation was unhelpful and difficult to understand the maintenance and operation system including installation instruction and technical manuals, because I think maintenance is not only what building staff do, it is also about something we should know about at least inside home features, we know nothing until we face a serious problem." Occupant 1 in TC.

"Other than air-conditioning, no other equipment had been serviced regularly." Occupant 5 in PRI.

There is a legal duty to perform an annual safety check on air-conditioning systems but not on home appliances and lighting fixtures, a point that is generally raised in the case of occupant complaints.

Building design and quality (BD&Q)

Design is considered in various sections of the LEED categories, for example in the 'innovation and design' (ID) category, in the way the windows should be positioned for daylight and access to views. Design plays an integral role in occupant experiences with their homes and surroundings. It also determines how the building is used and maintained, how the plumbing is configured, and where the services, such as elevators, are located. Even though design of the building and the apartments are considered in various sections of the LEED categories, the relevance of design in the context of the participating occupants differed. Analysis shows 60.1% of occupants are neutral or less satisfied with the building design and quality. This certainly emphasises the importance of further need for designers and construction industry professionals to review how to obtain higher levels of satisfaction with their design and finishing quality. As this part of the research highlights professional and occupant opinions, it is useful to query ‘What does visually attractive mean?’, when the majority of occupants were not impressed with the standard of design and they found modern provisions unattractive.

“Comparing to other buildings built in Dubai, I am not happy with the design and quality of this building, the finishing is really low quality and windows are not designed perfectly to have the best outside view.” Occupant 4 in PR I.

“Unfortunately, quality is often the first to be sacrificed in favour of cost savings and schedule reduction in the UAE after 2008 recession.” Occupant 2 (Architect) in TC.

Recreational areas in the building (RA)

Results show that occupants are far less satisfied with recreational areas in their buildings. Although two of the case-studied buildings mentioned that there are recreational and children’s play areas, but they do not seem to be at a satisfactory level for the occupants. This again needs to be reviewed by professionals and designers.

Green/ LEED-certified building (G/LEEDB)

Almost the majority are satisfied by living in LEED-certified buildings, but still 37.4% of them are neutral. Some of those who responded ‘neutral’ or ‘unsatisfied’ had their own definitions of what they know as to be green.

“I do not care if the building is LEED-certified or not but there are some minimum requirements such as greenery and recreational areas plus low energy bills and rental cost which are more important to me.” Occupant 3 in TC.

“I can’t understand about LEED certification properly. Why do I need to use a separate heater instead of having it in HVAC?” Occupant 4 in PR I.

Building location (BL)

Location relates to several credits in the LEED categories such as access to alternate transportation and amenities. Results show 47.3% of occupants are satisfied with the building's location, while 47.8% are neutral. Further discussion during interviews showed that many of them chose their buildings for its accessibility to work.

"I chose this location because of my work but it is not the best location in the city in terms of access to entertainment." Occupant 2 (Architect) in TC.

"Here is somewhere in the middle of dessert and I preferred to live nearer to the big shopping malls or at the beach. But still I am happy to live close to my work." Occupant 10 in HDS SS II.

Interior size (IS)

Interior size is not appealing, with more than half of the occupants being neutral or unsatisfied (Table 4.23).

"I am happy with the size of my bedrooms, but the living and dining space is too small for our family gatherings. Toilets are also very small." Occupant 10 in HDS SS II.

"I don't like the design of the building and layout of my apartment; all rooms are around the living area and there is no hallway to separate the private and public spaces." Occupant 7 in PR II.

"Comparing to rental cost and energy bills the space I have is very small." Occupant 5 in PRI.

Subsequently, there was evidence to suggest that poor layout and small spaces are reasons for lower satisfaction levels with the issue of interior size. This point reveals that modern construction is moving towards a gradual reduction in room sizes in homes.

Building privacy (BP)

The majority of the occupants (81.3%) are satisfied with privacy. Based on the interviews, privacy appeared to be a significant factor for residents.

"I am very happy with the privacy I have here, this is very important to me." Occupant 1 in TC.

Safety and security (S&S)

Results show a very high level of satisfaction with safety and security. S&S is generally very high in the UAE and it is not related to the specific building security design or management. Another factor that emerged from the occupant interviews were safety. Occupants mentioned that they felt relatively safe and secure in their homes. However, they felt unsafe when other occupants permit strangers into the building.

"Generally, I feel safe and secured in the UAE and in my home, but sometimes I see many strangers are entering the building and spending long party time, this makes me uncomfortable and unsafe." Occupant 6 in PR I.

This problem is again due to certain neighbour's social behaviour and not about building safety and security systems. Therefore, by improving socio-cultural environment **(Motivation A),** there is hoping to resolve such problems.

Outside view (OV)

65% of the occupants are unsatisfied with their view to the outside and 28.1% are neutral.

"I don't care about the view as I spend less time inside my home during the daytime." Occupant 4 in PR I.

"The reason that I am unhappy about the location is because it is in the middle of dessert and all I can see as view is sand." Occupant 10 in HDS SS II.

Purchase or rental price (PRP)

Purchase or rental price is extremely high due to the expensive lifestyle in the UAE, the cost of buying or renting is more than double compared to many other developing cities in the world. Although, it is still at the satisfactory level since the purchase price to annual income ratio is approx. 6.52 and rental affordability is 2.00 in Dubai. Despite the fact that properties are affordable, occupants are still extremely unsatisfied, with only 5 out of 203 being satisfied.

Low energy bills (LEB)

Only 26.1% of building occupants are satisfied with low energy bills and most of them are neutral or unsatisfied.

"My energy bills are lower than my previous home but still I am not really satisfied." Occupant 5 in PR I.

Accessibility to public transportation (APT)

Based on the results, only 22.7% of the occupants are satisfied and the majority of them are either neutral or unsatisfied. Previously, occupant use of public transport was reviewed revealing that very few occupants use public transport constantly, while so many of neutral ones might not even be interested in using it.

"I don't know how easy is to have access to public transportation because I never used it." Occupant 9 in HDS SS II.

"The access to public transportation is not very easy otherwise I would use it more frequently." Occupant 10 in HDS SS II.

Accessibility to work (AW)

The majority are satisfied with the access to their work.

Accessibility to supermarket and shopping centres (AS&SH)

77.8% of the occupants are satisfied with their access to shopping centres and supermarkets.

"I don't have access to the best shopping malls as here is not the best location in the city but still there are some shopping malls and supermarkets." Occupant 10 in HDS SS II.

Sufficient garden and greenery space (SG&G)

As mentioned before by one of the occupants, their level of satisfaction with greenery and recreational areas is very low. Results show that only 1 out of 203 occupants is satisfied while 99.5% of them are neutral or unsatisfied. However, these features are consistent with goals in a few of the LEED categories, but still there is both a lack of greenery and occupant satisfaction in these LEED-certified buildings.

"My building has a very limited supply of greenery." Occupant 2 (Architect) in TC.

Overall satisfaction with the home (OSH)

Based on Figure 4.5 satisfaction level of occupants (renters and owners) are high. Only 9 out of 203 occupants (4.4%) are unsatisfied. 30.5% ticked 'neutral' which is still considerable and is being investigated by the researcher during the interviews.

When prompted with a list of factors that may be considered benefits of a home, the majority stated that safety and security (94%) and the ability to keep the home at a comfortable temperature (84.2%) are the most satisfactory factors. The same two factors are mentioned during interviews with occupants who were strongly satisfied with their homes.

"I feel very good when I am at home alone in Dubai specially as a woman, because there is always a high level of safety and security in the UAE." Occupant 10 in HDS SS II.

"I am very satisfied with my home because my home layout is efficient, and I am comfortable due to the satisfactory temperature level during the whole year, my only problems are lack of greenery and high DEWA (energy) bills." Occupant 3 in TC.

As mentioned earlier occupancy period (Table 4.2) in a brand-new home without a full season's use is short therefore, it is reasonable for occupants to assume that their view of the home would be positive. Further investigation during interviews reveals that occupants are neutral or unsatisfied due to high energy bills, rental cost and lack of greenery and recreational areas.

"I like living in such a new home, but I would be happier if cost of rent and bills were lower, comparing to the size of my home as I pay more than what I get." Occupant 5 in PR I.

"Other than expensive lifestyle here, there is everywhere lack of green areas and worse than all are residential buildings while they just build the maximum of the plot without enough gardens and trees." Occupant 2 (Architect) in TC.

Table 4. 23 Occupant satisfaction and comfort level

	Strongly satisfied	Satisfied	Neutral	Unsatisfied	Strongly Unsatisfied
IAQ	23	127	37	15	1
TC	35	136	25	6	1
AC	18	100	73	11	1
NLC	37	126	31	8	1
ALC	35	113	45	9	1
BC	22	68	103	9	1
M&O	28	91	74	9	1
BD&Q	21	60	110	11	1
RA	11	6	89	87	10
G/LEEDB	1	123	76	1	2
BL	13	83	97	9	1
IS	10	78	108	6	1
BP	7	158	33	4	1
S&S	8	183	8	3	1
OV	1	13	57	96	36
PRP	1	4	26	105	67
LEB	6	47	85	53	12
APT	1	45	78	64	15
AW	1	138	52	8	4
AS&SH	1	157	38	5	2
SG&G	0	1	45	126	31
OSH	12	120	62	8	1
OSB	3	109	61	28	2

The results reveal that the overall satisfaction among occupants is significantly high. Further investigation from occupants revealed the reason for being unsatisfied which are the high purchase price and formalities costs.

"Comparing to the quality of what you get in the UAE, you should pay a lot as property cost together with many governmental and land department fees. Service charge is also very high approx. 30% of your rental cost." Occupant 1 in TC.

Overall satisfaction with the building (OSB)

Overall satisfaction with the building is very similar to the satisfaction with the home. Some occupants only complained about lack of storage.

"The layout of the building is OK but there is no space as storage somewhere in the building." Occupant 10 in HDS SS II.

"I wish I had a dedicated place to keep my bicycle and luggage." Occupant 7 in PR II.

Figure 4.5 shows the comparison between different factors level of satisfaction. '1' stands for 'strongly satisfied' and '5' for 'strongly unsatisfied' therefore, where the mean is smaller, then the level of satisfaction is higher. The comparison shows that the ability to keep the home at a comfortable temperature level (mean: 2.02) and safety and security (mean: 2.04) gained the highest satisfaction levels from occupants.

Further work is needed to understand the occupant perceptions of comfort and satisfaction, and how the increased awareness **(Knowledge)** may change their expectations.

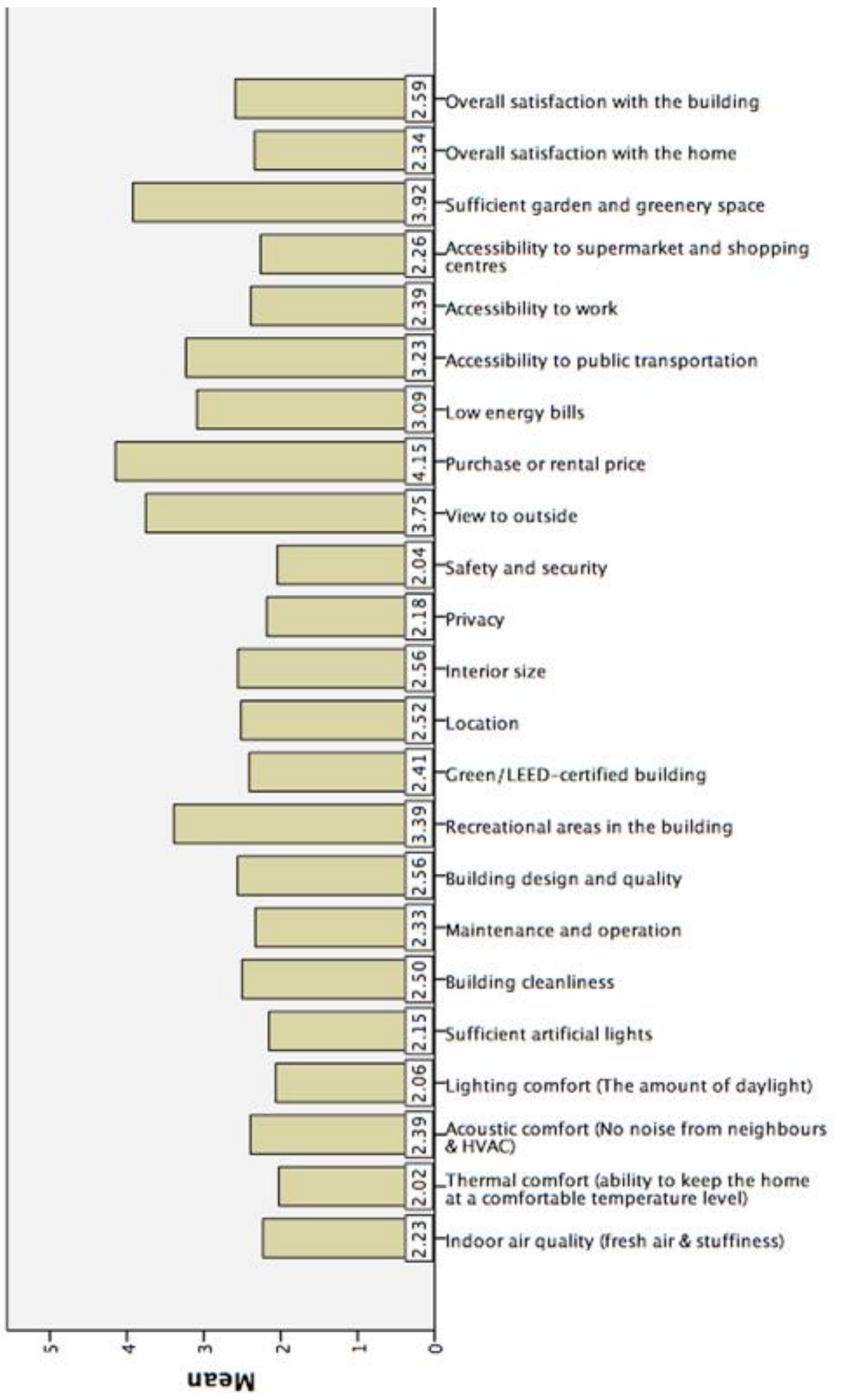

Figure 4. 5 Comparing the level of satisfaction between different factors

4.3.5 SECTION FIVE – OCCUPANT VIEW ON INFORMATION STRATEGIES

This section is about the influence that '**Knowledge**' may have on occupant behaviour, and the reasons behind the energy performance gap between assumed and actual in LEED-certified buildings. Therefore, occupants were asked to allow the researcher to investigate their views on management and information strategies.

Results in Table 4.24 show that most of the occupants are either not aware if a building management system is installed or mentioned that they are sure there is no such system. Only 26.6% of respondents were aware of such systems.

Table 4. 24 Occupant views on management and information strategies

		Frequency (n=203)	Percentage (%)
Awareness of building management system installation			
	Yes	54	26.6
	No	66	32.5
	Don't know	83	40.9
Awareness of energy management/ POE survey conduction by building manager/ developer			
	Yes	46	22.7
	No	64	31.5
	Don't know	93	45.8
Receiving reminder or feedback about recycling strategies from building manager			
	Yes	1	0.5
	No	169	83.3
	Don't know	33	16.3

Only 22.7% of the occupants mentioned there are energy management surveys and the rest either ticked ‘no’ or ‘don’t know’ (Table 4.24).

Some occupants were interested in learning about their behaviour outcome through surveys and feedback, in order to improve their current situation, and to help professionals and building managers to learn from past mistakes.

“Once I think there was an evaluation but without feedback to us. I like to know more about everything and receiving feedback on how we are behaving.” Occupant 4 in PR I.

Only 1 out of 203 occupants received reminder/ feedback and the majority (83.3%) have not received any guidelines about recycling strategies from the building manager (Table 4.24).

Availability of user’s guide/ manuals

Based on the results in Table 4.25, occupants are not generally satisfied with the information given to them about their home, as 53.2% have not received any guides/manuals.

Table 4. 25 Receipt of user’s guide/manuals when renting or buying the home

	Frequency (n)	Percentage (%)
Yes, I received a simple user guide/manual and understood it easily	40	19.7
Yes, I received a very complicated user guide/manual and could not understand it	12	5.9
No, I have not received any guides/manuals at the beginning and during my residency	108	53.2
I don’t remember	43	21.2
Total	203	100.0

Level of satisfaction with provided information and guides

Occupant level of satisfaction with the information providing within the different aspect of usage guide is reviewed in Table 4.26.

Figure 4.6 compares the level of satisfaction between these different aspects. The emergency guide is the most satisfactory factor according to half of the occupants (50.7%), while having the lowest mean (2.5). However, a day-to-day user guide and operation-maintenance guide are both at an acceptable satisfaction level.

Table 4. 26 Satisfaction level for the provided information and guide

	Strongly satisfied	Satisfied	Neutral	Unsatisfied	Strongly Unsatisfied
Day-to-day energy usage guide	29	68	76	21	9
Operation and maintenance guide	18	55	99	27	4
Emergency cases guide	25	78	74	17	9

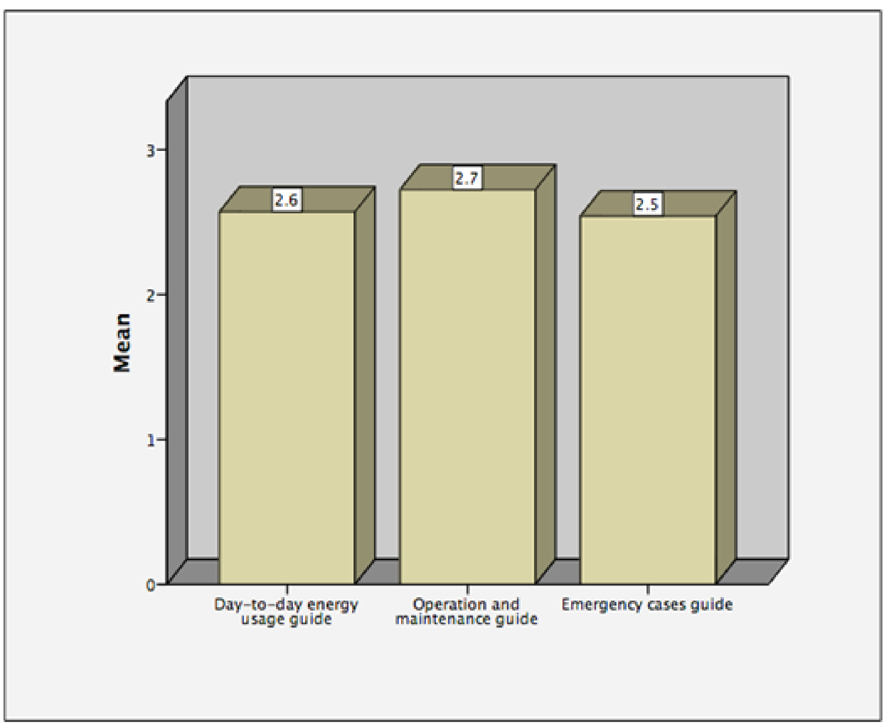

Figure 4. 6 Comparing occupant level of satisfaction with different aspects of user's guide

Preferred ways of receiving information and guides

Table 4.27 shows occupant preferred ways of receiving information on advice for different energy saving approaches.

Table 4.28 compares the level of importance for each preference. The key factors in order of importance are:

1. Electronically using email or the web,
2. Printed paper,
3. Video,
4. Practical demonstration and workshops.

Comparing both lower and upper values in Table 4.29, there is no significant difference between the first two factors and both ‘electronically using email/ web’ and ‘printed paper’ are almost at the same level of preference.

Table 4. 27 Preferred ways of receiving information and guide

	Ranking Votes				**Ranking**
	1st	2nd	3rd	4th	
Printed Paper	94	46	40	23	**2**
Electronically using email or the web	61	103	30	9	**1**
Video	19	35	100	49	**3**
Practical demonstration and workshops	29	18	34	122	**4**

The following statements from their interviews indicate some occupant major concerns:

“I prefer to have individual training inside my home.” Occupant 10 in HDS SS II.

"I thought if there will be the practical demonstration and they go through it a bit too quickly, I will not be able to take it all in, I would love to have a printout with all the information and everything." Occupant 7 in PR II.

"We did have all the manuals but some of them are so complicated that in the end you were just grabbing workmen off the site and saying, how does this work? So practical demonstration is needed together with such manuals." Occupant 9 in HDS SS II.

During the interview, one of the occupants who ticked 'other' mentioned that it is great to have individual training inside their homes:

"I like to have an individual training, and this should be available to those who require more assistance." Occupant 1 in TC.

Table 4. 28 One-sample statistics compare mean

	N	Mean	Std. Deviation	Std. Error Mean
Printed paper	203	1.96	1.057	.074
Electronically using email or the web	203	1.94	.790	.055
Video	203	2.88	.882	.062
Practical demonstrations and workshops	203	3.23	1.103	.077

There were more concerns about the benefit of such manuals during the interviews:

"If receiving guide helps everybody to save energy, I would love to learn and my preference is electronically using email or the web instead of wasting printed papers, I think this is greener." Occupant 2 (Architect) in TC.

"I definitely like to receive manuals which can be informative in printed paper or electronically otherwise I don't know how it can be helpful." Occupant 5 in PR I.

"I would want to know more by receiving guides." Occupant 3 in TC.

“There is no workshop or training to be relevant to the cooling system and ventilation. Giving some guides without reminding busy occupants can be useless, so it is good to have continuous feedback and reminders.” Occupant 4 in PR I.

The above statements clearly show that there is lack of information and guide provided to occupants while the process of providing information and feedback should be considered as an important part of building management system **(Knowledge)**.

Table 4. 29 One-sample test confidence interval

	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Printed paper	26.428	202	.000	1.961	1.81	2.11
Electronically using email or web	34.902	202	.000	1.936	1.83	2.05
Video	46.549	202	.000	2.882	2.76	3.00
Practical demonstrations and workshops	41.694	202	.000	3.227	3.07	3.38

4.3.6 RATIONALE FOR THE INTERVIEW WITH BUILDING OPERATORS (BOS)

Referring to the analysis of some parts of the questionnaire survey and interviews related to the effectiveness of communication and knowledge exchange between the occupants and building operators, only half of the occupants mentioned that they do recycling while the other half are not always doing so. They also mentioned they have not received user’s guide and information at the time of renting or buying their homes, and as a result, they are not completely aware of environmentally-friendly approaches that the LEED-certified buildings are designed for. Therefore, there is a need to ask the building operators certain questions in order to understand the occupant levels of involvement in recycling and green practices. It is also important to find out about the BOs level of effective communication, concerns, education, and awareness about improving the environmental quality of the building. Do they provide information/ feedback through POEs to their occupants to raise awareness and promote environmentally-friendly behaviour?

4.4 BUILDING OPERATORS (BOS) INTERVIEW RESULTS

After the analysis of the questionnaire survey and understanding the reasons behind certain behaviours coming from occupants and some of the possible motivational factors, interviews with building operators took place. The main purpose of the interviews was to clarify some issues raised in the survey and from the interviews with occupants. The researcher also hoped the interviews would help her to better understand the relationship between the building operators and occupants.

Five BOs from four LEED-certified buildings were interviewed (two BOs from one building). All of them had been working in their buildings for less than two years and they mentioned most of their occupants are also new, because the building is newly constructed. Four of them had building maintenance or management backgrounds with experience in similar buildings, but one BO started without any solid education or background in LEED-certified building operation. Due to the request from the BOs their answers were written with the information about their buildings and other specific personal information remaining confidential.

The four main questions informing the interviews with the five BOs are set out below, together with examples of their responses.

4.4.1 BOS AND OCCUPANTS ENVIRONMENTAL CONCERNS

1. *What actions or protection methods are you taking to save the environmental quality? And what is your opinion about environmental roles of occupants in their LEED-certified buildings?*

This part of interviews with building operators was aimed at recognising their levels of care about the environment while maintaining and operating their buildings.

The BOs mentioned that they are continually thinking of ways to make the buildings greener and more environmentally-friendly:

"We are maintaining greenery within the building's internal and external features to keep the beauty and cleanliness of the buildings." BO.

"We're not necessarily green, LEED certified doesn't necessarily mean green, I think some people confuse that. There's always things that we can do to improve, we always try to do that." BO.

"Occupants clean their individual homes and have nothing to do with other areas, there is no involvement by them as they don't have to, but this can be helpful." BO.

"I know we send out manuals to occupants, we are not instructed to or trained on how to inform or educate occupants." BO.

"The design team should be more involved; they should communicate information feedback to occupants. This can be the best way of evaluation to help everybody to learn from their mistakes." BO.

As a result of the BOs responses, it appeared the occupants needed to realise that their LEED-certified homes are only one of the stepping stones to achieving 'greenness' and that the role they play in the building can have a significant effect on the overall performance and the natural environment.

Currently, the BOs play significant roles in the upkeep and maintenance of such buildings and they believe occupants play only a minimal role. They also believe that design teams and professionals should be involved after operation in order to conduct proper evaluations and obtain feedback to help to improve the greenness approaches and energy use reduction.

4.4.2 BOS AWARENESS ABOUT OCCUPANT ENVIRONMENTAL ATTITUDES

2. *What do you do in terms of recycling strategies and methods to save electricity and water (E.g. use of the door sensors, lift sensors, light sensors, doors/ windows airtightness, etc.)?*

All of them mentioned that they do recycling for buildings, but occupants are not controlled and there is no continuous instruction and feedback on recycling strategies to occupants.

"We do consider recycling strategies and there are recycle bins available in the building, but occupants are not chased to do that, yes maybe that is very good to control their recycling strictly." BO.

"We are recycling papers; other residence waste is sent directly to the bin." BO.

All of them responded that they are using the door and light sensors in the parking and corridor areas. Further, they are using LED bulbs around the buildings.

Regarding water conservation, most of the BOs mentioned that the solutions for water reduction present problems. Even if occupants are 'broadly sympathetic' it was still thought that residents are not prepared to accept any type of water supply restriction and that they want enough water to do what they want. Some are seen to change their showerhead if they do not feel happy with low flow.

"The majority of the occupants agreed that the flow from their shower was sufficient for them. However, still some of them request for changes or they change things themselves." BO.

"As far as making that a greener building, we're looking at different ways of conserving their energy, i.e., conserving their costs in electricity and water and looking at our energy consumption and ways of conserving that." BO.

"We've done some things like changing some of the lighting to make it more sustainable. We are continuing what the LEED-certified status says to us and we're not done, we're going to continue, but since I have been here there were no strict guidelines from green agencies or authorities. Some concerns are kind of neglected such as the airtightness control." BO.

As highlighted above from the BOs interview results and based on the results from occupant interview, airtightness is an issue and currently it is considered to be very poorly dealt with.

Water usage results from both occupant and BOs interview results show that the amount of water consumption does not consider occupant training **(Knowledge)** or perception of the water supply. It appears most occupants will use the amount of water they want to satisfy their needs.

In both Prime Residence buildings (PR I & PR II), BOs responded that they were asked to monitor daily electricity and water usages of the building. In the HDS SS II and TC buildings the managers instructed those measurements should be taken on a weekly basis, rather than daily.

4.4.3 BOS AWARENESS ABOUT OCCUPANT SATISFACTION LEVEL

3. *Is there any serious complaint or dissatisfaction coming from occupants?*

BOs did not mention any serious occupant complaint or dissatisfaction with any major point:

"They have not complained about any major issues, maybe because the building is new and they are also new residents, all systems are working well. It is good to have occupancy satisfaction evaluation for us, but I never did that before, because there was no instruction or guideline for us." BO.

"We try our best to maintain their security and to keep the building clean, just once one of them complained about some garbage in the parking area and that was left by other tenants on the same day." BO.

This finding is in line with the results found in survey and interview with occupants. It seems that LEED-certified buildings can satisfy their occupants to an acceptable extent.

4.4.4 BOS LEVEL OF EDUCATION AND TRAINING

4. *Have you received any or enough information/ training on how to operate the LEED-certified buildings? Are there some guidelines or POEs from authorities or green agencies?*

BOs were not fully educated for maintaining LEED-certified buildings. Only one of them mentioned that he had some training.

"I received some lessons from building management to minimise energy consumption at the beginning." BO.

A training programme was the main consideration relating to this question, so BOs could learn how to save energy. BOs highlighted the same issue, stressing that even building developers did not give any training to building management:

"If there are some important guidelines to follow for LEED-certified buildings then someone should train us." BO.

BOs tried to do something to reduce consumption via internal management system based only on limited experience and a few training sessions. There are some guides available to owners, but they are not instructed to give guides, feedback, or education to their tenants:

"Building management provides related guides/ manuals to owners sometimes and it is not their responsibility to provide those guides/ manuals to tenants who are renting." BO.

There are no information/ guidelines from DEWA/ governmental authorities regarding energy usage: *"DEWA is not giving any special supports and the only thing is their leaflets."* BO.

"If there will be some encouragement from the government to reduce energy everybody will pay attention." BO.

Both Prime Residence buildings (PR I & PR II) BOs mentioned that there is an organisation called 'Leaf Green' that has been conducting energy surveys since 2013. However, other BOs mentioned there are no energy/POEs surveys being carried out by their management or developers:

"The feedback of occupant survey conducted by 'Leaf Green' was not received by us to share with occupants. If there are some occupants who said 'no, there is no survey' they were not in this building at that time. But there are no surveys from us or developers." BO.

"There is no evaluation and feedback, sometimes some tenants ask us if the building is operating properly and it will be good for them to know if we, as building managers and them as occupants of this building are doing well." BO.

BOs had a basic understanding of LEED as ‘green’ but not in specific detail, because they were more engaged with the building due to their organisational and managerial roles. The interviews showed that the BOs along with the maintenance staff play a significant role in managing and operating the facilities and services at each building. However, they are not responsible for educating occupants and/or making occupants aware of either positive or negative environmental behaviours or their building’s green features. This perspective supports the opinion that an absence of effective feedback from building controls **(Knowledge)**, even if the building is LEED-certified, led the occupants to conclude that they did not understand their building.

4.5 KEY RESULTS

The results of this study have shown that the occupants of LEED-certified buildings do not exhibit environmentally-friendly behaviour as one would expect from the occupants in these kinds of buildings. This research finding serves to confirm the conclusions cited in the literature review in Chapter 2 that green buildings do not necessarily make their occupants green and environmentally-sensitive. There is a need for such occupants to be educated **(Knowledge)** and motivated **(Motivation A&B)** if they are to learn to behave in an environmentally-friendly manner. The results from the pilot study revealed that occupants in LEED-certified buildings are not greener than those living in conventional buildings. The results of the main research study have highlighted the problems associated with current sustainable design; an initiative which requires considering each occupant’s lifestyle, behaviour, attitude, satisfaction, comfort, awareness and education together with the BOs’ environmental concerns, knowledge and education. Therefore, there is a need of involvement by industry professionals during occupancy phase.

The majority of occupants were young, the majority averaging between 30-49 with college/ university degrees and a good knowledge and understanding of sustainability. The majority were renters with an average occupancy number of two to four persons. This young generation seemed to have good levels of understanding about global warming and climate change, and when they were asked to mention the importance of climate change, more than 65% of them expressed concerns about the environment and considered climate change as a global threat. On the other hand, the findings show that while the majority are concerned about the environment and are aware of sustainability and climate change issues, only relatively few of them behave in an environmentally-friendly fashion in their daily lifestyle. It is fair to conclude that their attitudes and values are not leading them to behave in an environmentally-friendly manner. This outcome confirms the revelations from the literature review while Van Raaij & Verhallen (1983) cited authors who noted there are intervening constructs between attitude and behaviour. They mentioned knowledge as intervening factor and this research study adds on to that finding as the **Knowledge** should be to inform occupants towards environmentally-friendly behaviour.

Occupants explained that the main factor for purchasing and moving to the building was the location which is accessible to their workplaces. Energy efficiency remains a minor consideration for occupants when choosing a home, with the majority identifying it as the least important factor out of six choices.

In general, occupants displayed some positive attitudes towards environmental behaviour, such as energy and water conservation, but not for recycling and especially alternative transportation. The findings show that recycling behaviour is the least neglected behaviour in comparison to other environmentally sensitive conduct. Still few occupants constantly displayed positive attitudes towards recycling due to their knowledge, previous habits, culture, and beliefs. The majority of occupants emphasised how effortless it was to recycle or were unaware of recycle bin availability. The findings about using public transportation show that occupants relied on their vehicles for grocery shopping even during the wintertime and nice weather. Furthermore, none of the occupants mentioned they owned a hybrid car.

All interviewees thought that they are aware of airtightness; however, findings from interviews show that there is an issue with understanding of this term. Currently it is considered to be very poorly understood or implemented by both industry professionals and building occupants. They feel that there are educational and training issues that are yet to be addressed considered as **Knowledge**. Reinforcing results on factors that would inform and motivate occupants to take energy-saving measures, occupants say that somehow lower energy bills, combined with receiving cash back rewards on savings **(Motivation B)**, would encourage them to buy or rent a very energy-efficient home in a LEED-certified building, as well as reducing their levels of energy consumption.

The majority confirmed that their cooling system was responsive enough for their needs, so they are able to enjoy a satisfactory thermal comfort level. However, the findings showed that AC working hours, especially during summer days, were very high and that caused high energy bills. The other high rated satisfaction was due to privacy and security; in particular, the latter quality applied not only to their buildings but to the whole of the UAE.

Most of the respondents agreed that there was sufficient light in their homes during daylight hours in order not to need artificial light. However, there were some exceptions related to lack of daylight caused to inappropriate building design. The occupants also agreed that maintenance and operation is at an acceptable level, however, most of the occupants complained about the quality of their building materials and finishes. They also expressed their dissatisfaction with high energy bills, purchase, and rental cost and when asked if they had sufficient garden space and recreational areas, the majority of them were strongly dissatisfied. Based on building surroundings, the number of recreational areas is extremely low, despite the fact there are children’s playing areas; findings that indicate occupants are extremely dissatisfied with recreational areas and greenery. The overall satisfaction level expressed by those occupying homes in LEED-certified buildings is significantly high.

Although many occupants received instructions manuals and/or training on how to operate the technologies inside their apartments, it was widely recognised from the results that the quality of information is currently inconsistent and often inadequate or overly complicated, rendering the information incomprehensible and therefore of little value to the occupants. This problem was confirmed by the BOs who noted that there are not continuous POEs or information/ feedback processes implemented to raise awareness among occupants about the environmental outcomes of their behaviour.

The findings also showed that green buildings need a high level of occupant and BOs engagement and understanding for them to remain holistically green. Based on their feedback, both occupants and BOs are concerned about the environment; however, low levels of education, motivation, and coordination lead to minimal levels on environmentally focused activity from the building occupants. For example, occupants 9 and 10 are both residing in HDS SS II, while Occupant 9 is very well-informed and behaves in an environmentally-friendly way, occupant 10 is less-informed and is willing to receive more education. Creating such socio-cultural environment **(Motivation A)** can help occupants to exchange knowledge and encourage environmental behaviour among each other. Survey findings, reinforced by comments during the occupants and BOs interviews for this research, suggest that training and education **(Knowledge)** driven by good socio-cultural environment **(Motivation A)** and financial incentives **(Motivation B)** are key concerns.

Finally, the findings of this research showed that the occupants of LEED-certified buildings do not always exhibit environmentally-friendly behaviour, as there is lack of inclusion of occupant behaviour in LEED. Therefore, there is a need for developing a process or model to improve occupant behaviour. The researcher found the necessity for further analysis through SEM technique using AMOS on the same collected data (a procedure explained in detail in Chapter 3). Such an analytical focus would examine the interrelationships between occupant Attitude, Knowledge and Behaviour (AKB) to help the researcher to conclude and propose the solution. Further analysis is explained in detail in Chapter 5.

CHAPTER 5 - STRUCTURAL EQUATION MODELLING

5.1 INTRODUCTION

Factors affecting occupant behaviour were identified in Chapter 2. The results presented in Chapter 4, included a range of parameters related to occupant background, attitude, behaviour, satisfaction and knowledge in relation to LEED-certified buildings. This Chapter addresses the interrelationship between only three groups of mentioned parameters Attitude, Knowledge and Behaviour (AKB) through applying the Structural Equation Modelling (SEM) method using AMOS. The data was entered in SPSS to complete the analysis in Chapter 4. After that the same data in SPSS was used in AMOS for further analysis in this Chapter. This Chapter first presents the measurement model as a hypothesised model to review the interrelationships between AKB; after that there is a verification of the best fitting structural model, and finally the discussion of results and summary is presented.

5.2 BUILDING OCCUPANT ENVIRONMENTAL BEHAVIOUR MEASUREMENT MODEL

To investigate the interrelationships between different parameters known as AKB, SEM technique was used to develop a measurement model. Such a model refers to the implicit or explicit models that relate the latent/ unobserved variables to its indicators/ observed variables. SEM is known as a "statistical methodology that takes a confirmatory hypothesis-testing approach to the analysis of a structural theory bearing on some phenomenon" (Byrne, 2016). In this research study such structural interrelationships are modeled pictorially to bring a clearer conceptualisation of the theory, this hypothesised model can be tested statistically through the analysis of variables (Byrne, 2016). If the goodness-of-fit is satisfactory, the model shows that there are interrelationships among variables, but if it is inadequate, then the variables interrelationships are rejected.

SEM benefit is the usage of confirmatory factor analysis which can reduce measurement error by having multiple indicators, in the form of observed variables, per each latent variable. This model can also review the interrelationship between multiple latent variables. First the analysis of the hypothesised model using CFA is presented, which is a statistical technique in order to verify the structure of observed variables. In this part of the research study CFA allows the researcher to review the interrelationship between observed variables and their underlying latent variables affecting occupant behaviour.

Latent variables are also known as the unobserved variables, constructs or factors which are measured by their respective indicators (observed variables). Observed variables within questionnaires (Appendix B) include 5 different sections: i) building occupant background, ii) attitude, iii) behaviour, iv) satisfaction level and v) knowledge. Three sections of the questionnaire, those which defined Attitude (Section 2), Knowledge (Section 5) and Behaviour (Section 3), known as AKB in this research study, were chosen for further analysis. The answers to each question are considered to be observed variables while the whole AKB cluster are latent variables. It is the significance of interrelationships between them that should be measured, analysed and modeled.

Indicators are observed variables, also known as manifest variables or reference variables. At least three observed variables/ indicators are recommended which is acceptable and common practice, two is problematic, and with one measurement, error cannot be modeled (Bodoff & Ho, 2016). If models use only two observed variables / indicators per latent variable they are more likely to be failed and therefore error estimates might be unreliable. The six questions under attitude-related survey questionnaire (Section 4.3.2) were chosen as observed variables for ATTITUDE; twenty six questions were included for the behaviour-related survey questionnaire (Section 4.3.3) as observed variables for BEHAVIOUR and three questions related to provided information and guidelines (Section 4.3.5) were chosen for KNOWLEDGE.

Further analysis continued through SEM in AMOS that was categorised and coded as given below:

ATTITUDE

- ATT 1: View on climate change (Section 4.3.2a)
- ATT 2: Belief about the impact of energy use on the environment (Section 4.3.2b)
- ATT 3: Current lifestyle related to the environment (Section 4.3.2c)
- ATT 4: Environmentally-friendly lifestyle changes and comparison between now and 4 years ago (Section 4.3.2.d)
- ATT 5: Attitude and belief about green buildings (Section 4.3.2f)

- ATT 6: Considering the term LEED-certified while choosing the home (Section 4.3.2g)

BEHAVIOUR

- BEH rec 1: Occupant behaviour towards recycling papers (Section 4.3.3c)
- BEH rec 2: Occupant behaviour towards recycling plastic pieces (Section 4.3.3c)
- BEH rec 3: Occupant behaviour towards recycling glass (Section 4.3.3c)
- BEH rec 4: Occupant behaviour towards recycling metal pieces (Section 4.3.3c)
- BEH rec 5: Occupant behaviour towards recycling carton boxes (Section 4.3.3c)
- BEH wat 1: Using the washing machine economically (Section 4.3.3d)
- BEH wat 2: Using dishwasher economically (Section 4.3.3d)
- BEH wat 3: Using less water in toilets (Section 4.3.3d)
- BEH wat 4: Pressing both buttons on WC flush (Section 4.3.3d)
- BEH wat 5: Taking showers instead of bathing (Section 4.3.3d)
- BEH wat 6: Turning tap off when brushing teeth (Section 4.3.3d)
- BEH elec 1: Leaving appliances on standby mode (Section 4.3.3e)
- BEH elec 2: Turning off lights if they're not needed (Section 4.3.3e)
- BEH elec 3: Using low energy light bulbs (Section 4.3.3e)
- BEH elec 4: Using low energy labelled appliances (Section 4.3.3e)
- BEH elec 5: Setting the thermostat for air conditioning (Section 4.3.3e)
- BEH elec 6: Keeping AC off when windows are open (Section 4.3.3e)
- BEH elec 7: Keeping windows open during summer (Section 4.3.3e)
- BEH elec 8: Keeping windows open during winter (Section 4.3.3e)
- BEH elec 9: Closing windows shades/ blinds (Section 4.3.3e)
- BEH elec 10: Controlling doors/ windows airtightness (Section 4.3.3e)
- BEH light: Hourly usage of artificial lighting in a day (Section 4.3.3f)
- BEH ac win: Hourly working of AC in a winter day (Section 4.3.3g)
- BEH ac sum: Hourly working of AC in a summer day (Section 4.3.3g)
- BEH trans 1: Walking or cycling to your work/ supermarket (Section 4.3.3h)
- BEH trans 2: Using public transportation (Section 4.3.3h)

KNOWLEDGE

- KNOW 1: Day-to-day energy usage guide (Section 4.3.5)
- KNOW 2: Operation and maintenance guide (Section 4.3.5)
- KNOW 3: Emergency cases guide (Section 4.3.5)

In AMOS, a measurement model is a model with indicators/ observed / measured variables to each construct/ unobserved/ latent variable to assess goodness of fit and/or validity. The measurement model generated in AMOS is shown in Figure 5.1. The model shows the interrelationship between the latent/ unobserved variables to their indicators/ observed variables. The researcher designed this hypothesized measurement model based on her background and knowledge gained through the literature review in Chapter 2 of this research. The researcher is interested in studying theoretical constructs that cannot be observed directly. These abstract phenomena AKB are termed latent variables or constructs, or factors. For example, the researcher must operationally define the latent variable ‘behaviour’. For that, the unobserved/ latent variable is linked to one that is observable, in order to make its measurement possible. For example, assessment of the behaviour, after that, constitutes the direct measurement of an observed variable through the questionnaire survey.

Given this necessary bridging process between observed variables and unobserved variables AKB, it should now be clear why methodologists urge researchers to be circumspect in their selection of assessment measures (Byrne, 2016). Confirmatory factor analysis (CFA) is appropriately used when the researcher has some knowledge of the underlying latent variable structure. Based on knowledge of the theory, interrelationships between the observed measures and the underlying factors are postulated a priori and then this hypothesized structure is tested statistically. The model would then be evaluated by statistical means to determine the adequacy of its goodness-of-fit to the sample data.

Figure 5.1 shows that the CFA model focuses solely on the link between construct / latent variables and their measured variables. Within the framework of SEM, CFA represents what has been termed a measurement model and it is mainly specifies the measurement model which is a restricted factor model.

The primary task in this model-testing procedure is to determine the goodness-of-fit between the factors in the hypothesised model and the sample data. As such, the researcher imposes the structure of the hypothesised model on the sample data, and then tests how well the observed data fit this restricted structure. In Figure 5.1, these are all standardised factor loadings. These factor loadings are typically associated with the factor analysis, which shows correlations among latent variables (shown on arrows between latent variables; AKB with low loading e.g. 0.01, -0.04, 0.03). As shown on arrows, the numbers are not high loading closer to 1. These lower numbers might cause trouble and shows lower interrelationship between latent variables.

On the other hand, the factor loading between each latent variable and its observed variables is important to be higher, e.g. Attitude and its observed variables ATT3, ATT4, ATT5 & ATT6 with 0.03, 0.26, 0.12 & 0.22 are very low, which might be problematic.

Structural equation models are schematically portrayed using configurations of four geometric symbols:

i) An ellipse represents unobserved/ latent variables,

ii) A rectangle represents observed variables,

iii) A single-headed arrow (→) represents the reflective measurement model as shown the impact of one latent variable on its observed variables/ indicators in Figure 5.1 (regression/ directional path), and

iv) A double-headed arrow (↔) represents covariance or correlations between pairs of latent variables AKB shown in Figure 5.1 (non-directional path as there is no link).

In reviewing the model shown in Figure 5.1, we see that there are three latent variables known as AKB. As mentioned earlier six observed variables are considered to measure Attitude, three to measure Knowledge, and twenty-six to measure Behaviour. These thirty-five observed variables function as indicators of their respective underlying latent variables. Error (e1–e35) associated with observed variables represents measurement error, which reflects on their adequacy in measuring the related underlying factors AKB. In AMOS, error variance terms are represented as ‘e’ inside circles (or ellipses) with arrows to their respective measured/ observed variables (Byrne, 2016).

Structural equation modelling was used to define and quantify complex relations between the occupant environmental AKB as shown in Figure 5.1. It consists of two main components: i) the measurement model showing the interrelationships between latent variables AKB as shown in the ellipses with their measurement indicators as shown in the rectangles in Figure 5.1, and ii) the structural model, which imputes interrelationships between the latent variables AKB as shown in Figure 5.5.

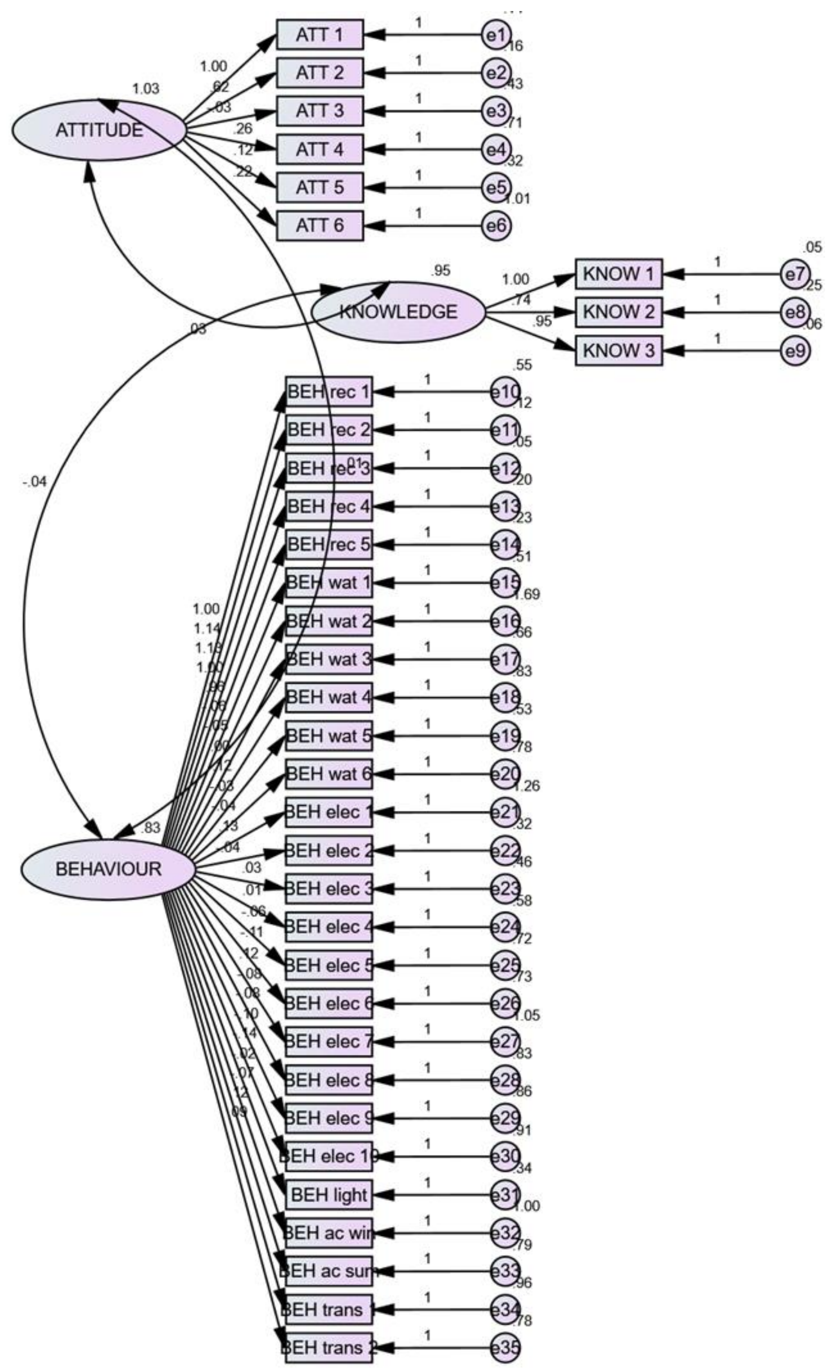

Figure 5. 1 Conceptual measurement model of interrelation between building occupant environmental AKB

$$t < \frac{1}{2} \times s(s+1)$$

The above equation if confirmed then the model in Figure 5.1 is over identified and therefore, it is acceptable:

t= items to be identified= 70 (35 'e' + 32 factor loading + 3 latent variables)

s= number of observed variables (35)

$$70 < \frac{1}{2} \times 35(35+1)$$

$$70 < 630$$

Based on the above result, it is confirmed that the model (Figure 5.1) is over identified.

5.2.1 MEASUREMENT MODEL EVALUATION OF FACTORS

It was crucial to review the significance of interrelationships between variables in the measurement model therefore, the measurement model was tested in AMOS software for reviewing the reliability and commonality of such a model. Measurement model was used to check the interrelationships among latent variables and their indicators/ observed variables and to investigate the strength and appropriateness of those interrelationships. In Figure 5.1 the measurement model is the reflective model as the direction of the arrows (→) are from latent variables (ellipses) to observed/ measured variables (rectangles). For example: the observed/ measured variables of the latent variable KNOWLEDGE are: i) day-to-day energy usage guide, ii) operation and maintenance guide, and iii) emergency cases guide, which were manifestations of KNOWLEDGE in the reflective measurement model. The observed/ measured variable (MV) is associated with the corresponding latent variable (LV) by a liner regression in this reflective measurement model:

$$MV = \omega\ LV + ð$$

where 'ω' shows the absolute contribution of a measured variable (MV) to the corresponding latent variable (LV), and it is called the outer loading. The range of 'ω' is [-1, 1]. The 'ð' represents the measurement error.

The list below explains the acceptable and good fit data range (Iacobucci, 2010; Byrne, 2016) and checks all the parameters in Table 5.1 related to the data for Figure 5.1.

- Ratio of minimum discrepancy to the degrees of freedom (CMIN/ DF) adjusts the chi-square by computing the ratio of the minimum discrepancy to degrees of freedom.

It ranges from 1-2 with values closer to one indicating better fit. In Table 5.1, CMIN/DF is 6.187 which is not a good fit, upper threshold is 5.

- Goodness of fit index (GFI); GFI > 0.9 means satisfactory fit; GFI is a test whether the maximum likelihood estimate of the hypothesised model fit to the data set. It ranges from 0-1 and higher values indicate better fit. GFI in Table 5.1 is 0.478 which is ranging between 0-1 but still not completely satisfactory.
- Adjusted goodness of fit (AGFI) favours parsimony, AGFI > 0.90 is good fit. In this Table, AGFI is 0.410 and is not a good fit.
- Incremental fit index (IFI) is the ratio of the difference between the hypothesised and baseline model degrees of freedom and discrepancy. It ranges from 0-1 with larger values indicating better fit. IFI in Table 5.1 is 0.417 and it is within the range, but it is better to be closer to 1 for a better fit.
- Normed fit index (NFI); NFI > 0.9 means satisfactory fit and value greater than 0.80 suggests a good fit. An NFI of 0.95 indicates the model of interest improves the fit by %95 relative to the model. In Table 5.1, NFI is 0.375 and it is not satisfactory.
- Non-normed fit index (NNFI) is preferable for smaller samples. NNFI is also called the Tucker-Lewis index (TLI). TLI > 0.9 means satisfactory fit; TLI compares degrees of freedom and discrepancy between baseline model and those of the hypothesised model. It ranges from 0-1 with larger value indicating better fit. TLI is 0.372 which is within the range, but it is not the closer to 1, hence, it’s not satisfactory.
- Comparative fit index (CFI); CFI > 0.9 means satisfactory fit. The CFI compares the fit of a baseline model to the data with the fit of the hypothesised model to the same data and it ranges from 0-1, with larger values indicating a better fit. It is 0.412 in Table 5.1, although it is within the range, but it is not closer to 1 and therefore, it’s not the best fit.
- Relative fit index (RFI) is also known as RHO1, is not guaranteed to vary from 0 to 1. RFI closer to 1 indicates a good fit. RFI in Table 5.1 is 0.332 and it is not the best fit although it is within the range.
- Root mean square residual (RMR) computes the residual differences between model prediction and data set and it also takes the square root of the result. It ranges from 0-1 with smaller values indicating better fit. RMR is 0.133 in Table 5.1 and it is within the range, although it is not the best fit.

- Root mean square error of approximation (RMSEA); RMSEA <0.05 is a good fit and <0.08 is an acceptable fit. The value of the RMSEA of about .05 or less would indicate a close fit of the model in relation to the degrees of freedom. This figure is based on subjective judgment. It cannot be regarded as infallible or correct, but it is more reasonable than the requirement of exact fit with the RMSEA = 0.0. There is an opinion that a value of about 0.08 or less for the RMSEA would indicate a reasonable error of approximation and there is no need to employ a model with a RMSEA greater than 0.1. In Table 5.1, RMSEA is bigger than 0.08 and it is 0.160 which is not even an acceptable fit. The columns labeled LO 90 and HI 90 contain the lower limit and upper limit of a 90% confidence interval for the population value of RMSEA. In Table 5.1, LO 90 is 0.155 and HI 90 is 0.165.
- The parsimony ratio (PRATIO) is the ratio of the degrees of freedom in the model to degrees of freedom. PRATIO is not a goodness-of-fit test itself but it is used in goodness-of-fit measures like PNFI and PCFI. PRATIO is 0.936 in Table 5.1 and it will be a better fit with a smaller value.
- The parsimony goodness of fit index (PGFI) is a variant of GFI which penalises GFI by multiplying it times the ratio formed by the degrees of freedom in the model divided by degrees of freedom in the independence model. AMOS computes PGFI for Figure 5.1 and Table 5.1. PGFI is 0.423 while closer to 1 is a better fit therefore, it is not a good fit.
- The parsimony normed fit index (PNFI) is equal to the PRATIO times NFI (see above). PNFI in Table 5.1 is 0.351 while closer to 1 is a better fit.
- The parsimony comparative fit index (PCFI), is equal to PRATIO times CFI (see above). The model with the higher PCFI closer to 1 is better and in Table 5.1 PCFI is 0.386, hence, it's not a good fit.
- PCLOSE tests the null hypothesis that RMSEA is not greater than .05. If PCLOSE is less than .05, we reject the hypothesis and conclude that the computed RMSEA is greater than .05, indicating lack of a close fit. In Table 5.1 PCLOSE is 0 which is less than 0.05, RMSEA is 0.160 which is greater than 0.05 therefore there is lack of close fit in this model (Figure 5.1).

Table 5. 1 Outcome of conceptual measurement model fit

CMIN

Model	CMIN	DF	P	CMIN/DF
Default model	3445.947	557	.000	6.187

RMR, GFI

Model	RMR	GFI	AGFI	PGFI
Default model	.133	.478	.410	.423

Baseline Comparisons

Model	NFI	RFI	IFI	TLI	CFI
Default model	.375	.332	.417	.372	.412

Parsimony-Adjusted Measures

Model	PRATIO	PNFI	PCFI
Default model	.936	.351	.386

RMSEA

Model	RMSEA	LO 90	HI 90	PCLOSE
Default model	.160	.155	.165	.000

5.2.2 ANALYSIS AND MODIFICATION OF THE MEASUREMENT MODEL

In order to modify the measurement model there were three main steps (Kline, 2005) which are explained as follow:

- The first step was to delete paths that have very low factor loadings (***Step 1***),
- The second step was to co-vary variables mentioned by the modification indices (MI) table as multi-co-linearity (***Step 2***), and
- The third step was to eliminate observed variables with very high values in the standardised residual correlation matrix (***Step3***).

The path coefficient and GOF sometimes reveal the need to modify models in SEM, which can result in selection of a best fitting model falling within theoretical expectation and satisfies the GOF measures (Byrne, 2010).

Step 1:

As the first step some of the observed variables were eliminated from the measurement model as shown below:

- From Attitude: ATT 3, ATT 5, ATT 6 were eliminated, ATT 4 (0.26) kept as it is an important observed variable to support the latent variable A (Attitude).
- From Behaviour: BEH wat 1, BEH wat 2, BEH wat 5, BEH wat 6, BEH elec 2, BEH elec 5, BEH elec 6, BEH elec 8, BEH elec 9, BEH elec 10, BEH light, BEH ac win, BEH ac sum, and BEH trans 2 were eliminated.

This was due to very low factor loading shown on the arrow between latent variable and observed variables in Figure 5.1. Figure 5.2 is the revised measurement model after Step 1. The reason of not eliminating all the observed variables with low factor loading for latent variable B (Behaviour) is to keep some of the water and energy savings behaviours in the model to check whether the good model fit can be confirmed including some of them.

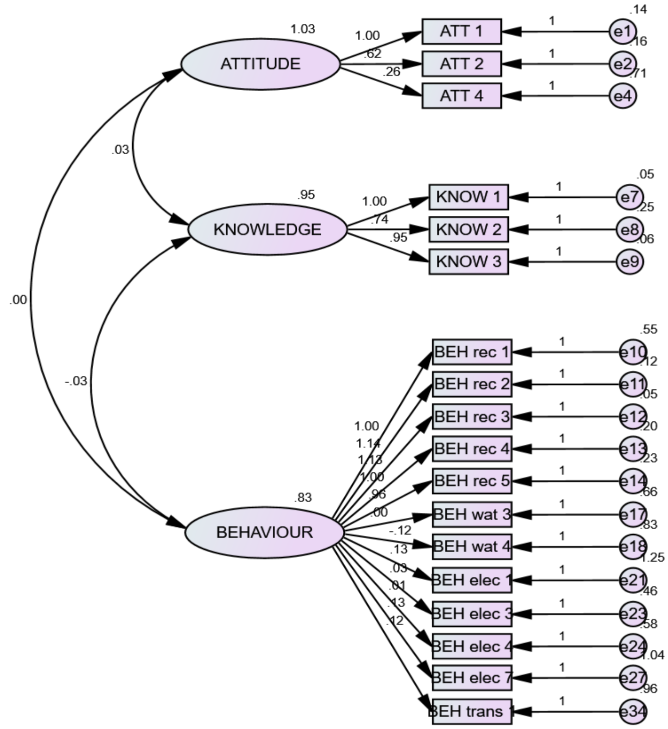

Figure 5. 2 Conceptual measurement model of interrelation between building occupant environmental AKB after Step 1

$$t < \frac{1}{2} \times s(s+1)$$

The above equation if confirmed then the model in Figure 5.2 is over identified and therefore, it is acceptable:

t= items to be identified= 36 (18 ‘e’ + 15 factor loading + 3 latent variables)

s= number of observed variables (18)

$$36 < \frac{1}{2} \times 18(18+1)$$

$$36 < 171$$

Based on the above result, it is confirmed that the model (Figure 5.2) is over identified.

Modification Indices (MI)

If the model fit is not adequate, then it is common to modify the model by deleting factors that are not significant. To facilitate this, SEM can compute Modification Indices (MI) for each fixed factor. MI values are the minimum amount that the chi-square is expected to be reduced. MI values are often used to modify models for achieving a better fit hoping for the significant improvement in the model, but this process should be done carefully and with theoretical justification (Byrne, 2016). Blind use of MI brings the risk of capitalisation of chance and model adjustments which make no sense (Silvia and MacCallum, 1988). As mentioned, improvement in the fit with MI is measured by a reduction in chi-square, in another word, "a finding of chi-square significance corresponds to rejecting the model as one which fits the data" (Byrne, 2016).

The default threshold for MI can be set to 4. The researcher can start to set a higher value if wanted to avoid unnecessary elimination of the observed variables and this process is continued until an adequate fit is achieved. In this research study the researcher set the threshold at 10 therefore, variables valued as equal to, or more than 11 need to be eliminated in Step 2. The reason of setting the threshold higher was due to reviewing the confirmation of model fit while eliminating a smaller number of observed variables. If the model fit is improved significantly, then there is no need to reduce the threshold and eliminate more variables but if it is not confirmed as an improved model fit, then the researcher can set the threshold at the smaller value closer to MI default threshold which is 4.

The 'e' numbers relate to error variance for each observed variable. The interrelationships between all error variances among each other and with the latent variables are reviewed in Table 5.2., indicating MI figures related to Figure 5.2.

MI figures are the covariance between error variance of each observed variable among each other and with each of their latent variables AKB.

Table 5. 2 Modification Indices (MI) after Step 1

Covariance:

			M.I.
e34	↔	KNOWLEDGE	4.324
e27	↔	KNOWLEDGE	7.950
e27	↔	ATTITUDE	5.559
e24	↔	KNOWLEDGE	10.178
e24	↔	e27	34.311
e23	↔	KNOWLEDGE	7.935
e23	↔	ATTITUDE	5.067
e23	↔	e27	11.685
e23	↔	e24	84.190
e21	↔	e27	119.003
e21	↔	e24	15.784
e21	↔	e23	9.645
e18	↔	e27	4.436
e17	↔	KNOWLEDGE	6.385
e17	↔	e27	5.146
e14	↔	KNOWLEDGE	4.569
e14	↔	e21	11.573
e14	↔	e17	4.012

			M.I.
e13	↔	e14	75.421
e12	↔	e17	5.022
e11	↔	KNOWLEDGE	5.631
e11	↔	e21	5.653
e11	↔	e14	14.860
e11	↔	e13	9.063
e10	↔	e34	9.162
e10	↔	e14	7.750
e10	↔	e13	12.434
e10	↔	e11	34.255
e9	↔	e14	5.735
e8	↔	e18	5.077
e8	↔	e13	5.095
e7	↔	e14	7.444
e4	↔	e27	4.408
e4	↔	e18	10.129
e2	↔	e34	7.108

Step 2:

Step 2 was to review model fit results in the MI table after step 1 modifications, the observed variables which are above 10 in Table 5.2 were covaried (shown in **underlined** **red colour**) if they were in the same factor.

Co-varying can be seen in Figure 5.3 as curved small two-way arrows between error variance (e) of observed variables in the same factor, which is in this case ‘Behaviour’, and they represent covariant or correlation between pairs of variables as follow:

- e10 ⇔ e11
- e10 ⇔ e13
- e11 ⇔ e14
- e13 ⇔ e14
- e14 ⇔ e21
- e21 ⇔ e24
- e21 ⇔ e27
- e23 ⇔ e24
- e23 ⇔ e27

Figure 5.3 is the modified measurement model after step 2, however, it is not yet the best model fit due to the existence of low factor loading shown between each latent variable and its observed variables. There is still some factor loading below 0.1 shown on arrows in Figure 5.3.

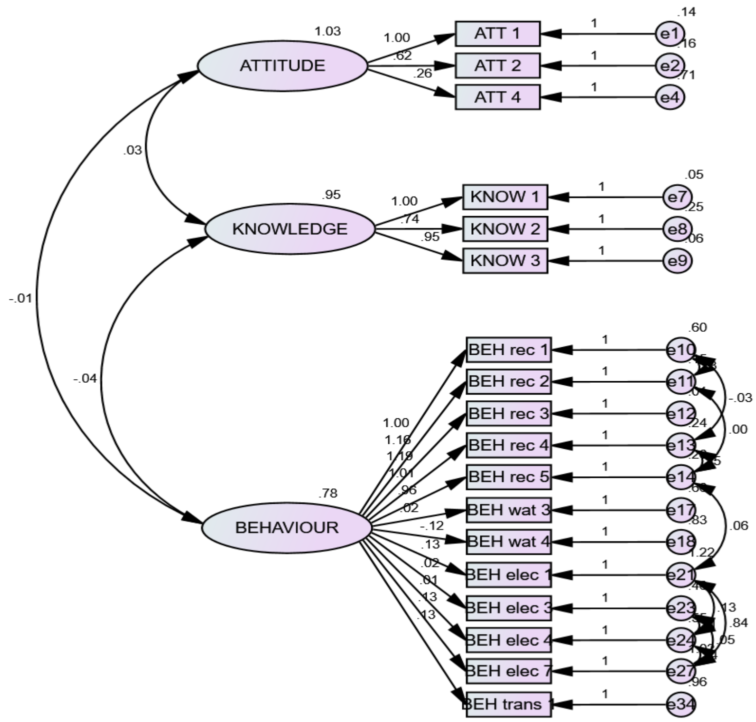

Figure 5. 3 Conceptual measurement model of interrelation between building occupant environmental AKB after Step 2

Step 3:

The third step was to go through standardised residual covariance in Figure 5.3 after correlating errors and delete some of the observed variables above 0.1. Different trials were done, and the best outcome was to eliminate these observed variables in Behaviour: BEH wat 3, BEH wat 4, BEH elec 3, BEH elec 4, BEH elec 7, and BEH trans 1.

The resultant best fitting measurement model can be seen in Figure 5.4, based on the information that is presented in Table 5.3 and Table 5.4.

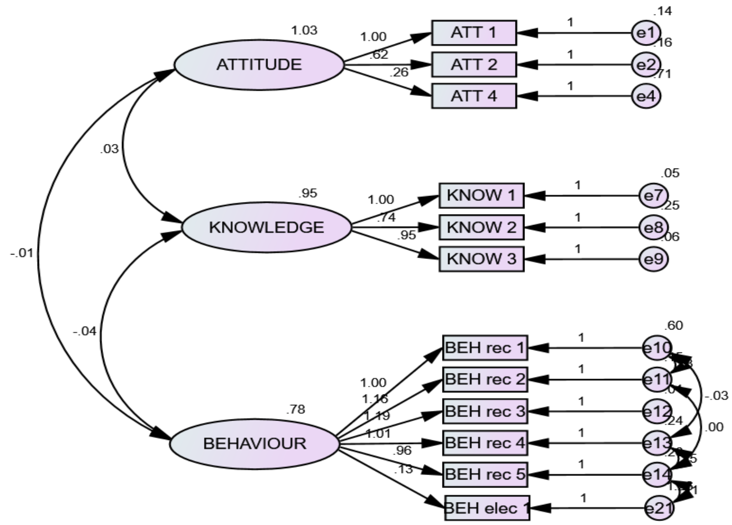

Figure 5. 4 Best fitting measurement model of interrelation between building occupant environmental AKB after Step 3 (Final Measurement Model)

$$t < \frac{1}{2} \times s(s+1)$$

The above equation if confirmed then the model in Figure 5.4 is over identified and therefore, it is acceptable:

t= items to be identified= 24 (12 ‘e’ + 9 factor loading + 3 latent variables)

s= number of observed variables (12)

$$24 < \frac{1}{2} \times 12(12+1)$$

$$24 < 78$$

Based on the above result, it is confirmed that the model (Figure 5.4) is over identified.

The list below checks all the parameters in Table 5.3 related to the data for Figure 5.4:

- CMIN/DF ranges from 1-2 with values closer to 1 indicating a better fit. In Table 5.3 CMIN/DF is 1.273 which is a good fit.
- GFI ranges from 0-1 and higher values indicate better fit. GFI in Table 5.3 is 0.954 which is ranging between 0-1 and it’s completely satisfactory.
- AGFI > 0.90 is a good fit. In Table 5.3 AGFI is 0.922 and it is satisfactory.

- IFI ranges from 0-1 with larger values indicating better fit. IFI in Table 5.3 is 0.994, it is within the range and closer to 1 which is a good fit.
- NFI of 0.95 indicates the model of interest improves the fit by 95% relative to the model. In Table 5.3 NFI is 0.974 and it is satisfactory.
- TLI > 0.9 means satisfactory fit. TLI ranges from 0-1 with larger value indicating better fit. In Table 5.3, TLI is 0.992 which is within the range and it is satisfactory.
- CFI ranges from 0-1 and lager values indicating better fit. It is 0.994 in Table 5.3 and it is within the range therefore, it is a good fit.
- RFI close to 1 indicates a good fit. RFI in Table 5.3 is 0.962 and it is a good fit.
- RMR ranges from 0-1 with smaller values indicating better fit. RMR is 0.044 in Table 5.3 and it is within the range, however, the better fit should be smaller and closer to 0.
- In Table 5.3 RMSEA is smaller than 0.08 and it is showing 0.037 which is a close fit. The columns labeled LO 90 and HI 90 contain the lower limit and upper limit of a 90% confidence interval for the population value of RMSEA. In this Table LO 90 is 0.000 and HI 90 is 0.063.
- PRATIO is 0.697 in Table 5.3 and it is smaller now therefore, it indicates an acceptable fit.
- PGFI for Figure 5.4 and Table 5.3 shows 0.563 which is an acceptable fit.
- PNFI in Table 5.3 is 0.679, it got closer to 1 and therefore, it is more acceptable.
- The model with the higher PCFI is better and in Table 5.3 it is 0.693 which is acceptable.
- In Table 5.3 PCLOSE is 0.777 which is now more than 0.05, RMSEA is 0.037 which is less than 0.05 therefore, the hypothesised model (Figure 5.4) is confirmed as it indicates all good fits.

Table 5. 3 Best fitting measurement model

CMIN

Model	**CMIN**	**DF**	**P**	**CMIN/DF**
Default model	58.560	46	.101	1.273

RMR, GFI

Model	**RMR**	**GFI**	**AGFI**	**PGFI**
Default model	.044	.954	.922	.563

Baseline Comparisons

Model	**NFI**	**RFI**	**IFI**	**TLI**	**CFI**
Default model	.974	.962	.994	.992	.994

Parsimony-Adjusted Measures

Model	**PRATIO**	**PNFI**	**PCFI**
Default model	.697	.679	.693

RMSEA

Model	**RMSEA**	**LO 90**	**HI 90**	**PCLOSE**
Default model	.037	.000	.063	.777

The GOF indices seems acceptable, as shown in Table 5.3. Table 5.4 compares the conceptual measurement model and the fitting measurement model which reveals great improvements in the outcome of the best model fit.

Table 5. 4 Summary of GOF results for both conceptual and best fitting measurement models

Goodness-of -fit (GOF) measures	Recommended level of GOF measures	Conceptual measurement model	Best fitting measurement model
CMIN/DF	1 (very good) - 2 (threshold)	6.187	1.273
Root mean sq. Error of approx. (RMSEA)	>0.05 (very good) - 0.1 (threshold)	0.160	0.037
Root mean sq. Residual (RMR)	0 - 1 (Smaller values = better fit)	0.133	0.044
Goodness-of fit index (GFI)	0 (no fit) - 1 (perfect fit)	0.478	0.954
Comparative-fit index (CFI)	0 (no fit) - 1 (perfect fit)	0.412	0.994
Incremental-fit index (IFI)	0 (no fit) - 1 (perfect fit)	0.417	0.994
Tucker-Lewis index (TLI)	0 (no fit) - 1 (perfect fit)	0.372	0.992

5.2.3 PATH COEFFICIENT OF OBSERVED VARIABLES LOADING ON THE LATENT VARIABLES

The standardised path coefficient is also known as factor loading which mainly indicates the strength of the observed variables that measure the latent variables in the best fit measurement model. Values of factor loading equal to, or greater than 0.40 with significant p value< 0.05, can indicate strong measurement, while values closer to 1 indicate much stronger measurement (Byrne, 2010; Li et al., 2005).

The entire path coefficient in Figure 5.4 (the best fit measurement model) is positive and significant at level p<0.05 (Table 5.5- Regression weight) except BEHelec1 and ATT4, while the rest are supported. Table 5.5 shows the standardised path coefficient of observed/ measured variables impact on the latent variables ranged from 0.4 to 1.18, which reveals that the observed variables significantly measure the latent variables except for ATT 4 (being environmentally friendly) and BEH elec 1 (appliances on standby mode).

Table 5. 5 Regression weights

			Estimate	S.E.	C.R.	P
ViewOnClimateChange	<---	ATTITUDE	1.000			
EnergyUseImpact	<---	ATTITUDE	.623	.107	5.832	***
BeingEnvironmentallyFriendly	<---	ATTITUDE	.262	.070	3.751	***
DayToDayEnergyUsageGuide	<---	KNOWLEDGE	1.000			
OperationMaintenanceGuide	<---	KNOWLEDGE	.735	.039	18.751	***
EmergencyCasesGuide	<---	KNOWLEDGE	.953	.029	32.674	***
RecyclingPapers	<---	BEHAVIOUR	1.000			
RecyclingPlastic	<---	BEHAVIOUR	1.165	.065	18.014	***
RecyclingGlass	<---	BEHAVIOUR	1.187	.076	15.603	***
RecyclingMetal	<---	BEHAVIOUR	1.009	.076	13.281	***
RecyclingCartonBoxes	<---	BEHAVIOUR	.964	.072	13.304	***
AppliancesOnStandby	<---	BEHAVIOUR	.126	.090	1.396	.163

5.2.4 CORRELATION AND COVARIANCE COEFFICIENT

Table 5.6 and 5.7 show the weakness of the correlations and covariant relationships among the latent variables. This interrelationship indicates that the latent variables do not influence one another greatly with estimate correlation value of -0.037, 0.028 and -0.007 which are not above the minimum threshold of 0.4. All covariance estimates are not significant at level $p < 0.05$. The standard errors (S.E.) do not present any extremely large or small values (outliers) but the critical ratios (CR) present small values therefore, all correlations between the latent variables are not totally supported. In the other word there is no strong interrelationship between AKB in this research, however, each of them is supported by its observed variables and GOF indices had great improvements based on the analysis in Table 5.4.

Table 5. 6 Covariances

			Estimate	**S.E.**	**C.R.**	**P**
KNOWLEDGE	<-->	BEHAVIOUR	-.037	.062	-.588	.556
ATTITUDE	<-->	KNOWLEDGE	.028	.074	.379	.705
ATTITUDE	<-->	BEHAVIOUR	-.007	.067	-.102	.918

Table 5. 7 Correlations

			Estimate
KNOWLEDGE	<-->	BEHAVIOUR	-.042
ATTITUDE	<-->	KNOWLEDGE	.028
ATTITUDE	<-->	BEHAVIOUR	-.008

5.3 STRUCTURAL MODEL VALIDATION

The general SEM model can be divided into two sub-models: i) a measurement model and ii) a structural model. The measurement model, as shown in previous section of this Chapter, defines interrelationships between the latent variables and their observed variables (Byrne, 2016). Vice versa, the structural model defines interrelationships among the latent/ unobserved variables. These interrelationships specify how particular latent variables directly or indirectly influence or make changes in the values of certain other latent variables in the model (Byrne, 2016).

Therefore, the measurement model is a hypothesised model to specify a model with indicators/ observed/ measured variables to each of their construct/ latent variables in order to assess goodness of fit, validity, etc. Whereas, the structural model is to develop a model with dependence interrelationships among construct/ unobserved/ latent variables.

In this part of the research analysis, there is a requirement for testing the hypothesised dependence interrelationships among latent variables AKB after testing the measurement model, then the structural model should be specified and tested. Hence, based on the characteristics of the best model fit in the previous section, the measurement model and the existing models reviewed in Chapter 2 of this research study, the structural model (Figure 5.5) has been conceptualised.

The difference between Figure 5.5 in this section and Figure 5.4 is:

- Behaviour is not affecting Attitude and Knowledge, while in Figure 5.4 they are all interrelated and influencing each other as it was a measurement model.
- The researcher made a one-way interrelationship from Attitude and Knowledge to Behaviour and therefore, behaviour is endogenous. As shown on the arrows in Figure 5.5 Attitude to Behaviour measures at -0.01 and Knowledge to Behaviour measures at -0.04. based on this data and the analysis shown in Table 5.8, their interrelationship is not significant.

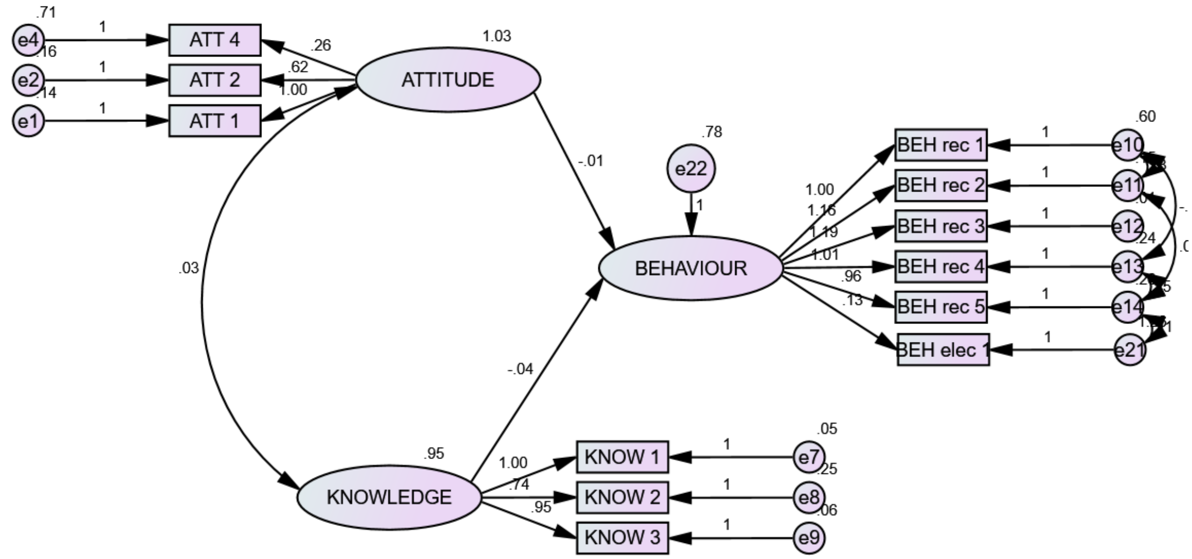

Figure 5. 5 Best fitting structural model

Estimate values equal to or greater than 0.40 with significant p value< 0.05 indicate strong measurement while values closer to 1 indicate stronger measurement (Byrne, 2010). In Table 5.8, the estimate for regression weight, covariance and correlation are all below 0.40, without a significant 'p' value. Only the estimate value for Knowledge variance is 0.952 and for Attitude variance is 1.033 with significant 'p' value. Therefore, the interrelationship is not very significant between these three latent variables.

The standard errors (S.E.) do not present any extremely large or small values (outliers) and as suggested by Byrne (2010) the model is reasonably good fit, on the other hand (S.E.) should not be extremely a small value close to zero as it indicates a poor model based on explanation by Bentler & Bonnet (1980). The critical ratios (CR) present small and/ or negative values for regression weight, covariance, and correlation and only for Knowledge and Attitude variance CR is high therefore, all correlations between the latent variables are not totally supported. In the other word, there is no strong interrelationship between AKB in this research, however each of them is supported by its observed variables as shown in Table 5.10 for GOF indices.

<u>Table 5. 8 Estimates/ scalar estimates/ maximum likelihood estimates</u>

Regression weights:

			Estimate	S.E.	C.R.	P
BEHAVIOUR	<---	KNOWLEDGE	-.038	.065	-.587	.557
BEHAVIOUR	<---	ATTITUDE	-.006	.065	-.086	.931

Covariances:

			Estimate	S.E.	C.R.	P
ATTITUDE	<-->	KNOWLEDGE	.028	.074	.379	.705

Correlations:

			Estimate
ATTITUDE	<-->	KNOWLEDGE	.028

Variances:

	Estimate	S.E.	C.R.	P
ATTITUDE	1.033	.205	5.030	***
KNOWLEDGE	.952	.101	9.406	***

The list below checks all the parameters in Table 5.9 related to the data for Figure 5.5:

- CMIN/DF ranges from 1-2 with values closer to 1 indicating a better fit. In Table 5.9 CMIN/DF is 1.273 therefore, it is a good fit.

- GFI ranges from 0-1 and higher values indicate better fit. GFI in Table 5.9 is 0.954 which is closer to 1, hence, it is completely satisfactory.
- AGFI > 0.90 considered as a good fit. In Table 5.9 AGFI is 0.922 and it is satisfactory.
- IFI ranges from 0-1 with larger values indicating better fit. IFI in Table 5.9 is 0.994 which is within the range and closer to 1 and therefore, it is a good fit.
- NFI of 0.95 indicates the model of interest improves the fit by %95 relative to the model. In Table 5.9 NFI is 0.974 and it is satisfactory.
- TLI ranges from 0-1 with larger value indicating better fit. TLI is 0.992 in Table 5.9 which is within the range and it is satisfactory.
- CFI ranges from 0-1 and larger values indicating better fit. It is 0.994 in Table 5.9 and it is within the range, hence, it is a good fit.
- RFI close to 1 indicates a good fit. RFI in Table 5.9 is 0.962 and it is satisfactory.
- RMR is 0.044 in Table 5.9 and it is the better fit as it is smaller and closer to 0.
- In Table 5.9 RMSEA is smaller than 0.08 and it is showing 0.037 which is a close fit. The columns labeled LO 90 and HI 90 contain the lower limit and upper limit of a 90% confidence interval for the population value of RMSEA. In this case LO 90 is 0.000 and HI 90 is 0.063.
- PRATIO is 0.697 in Table 5.9 and it is smaller now which indicates an acceptable fit.
- Table 5.9 shows PGFI equals 0.563 which is an acceptable fit.
- PNFI in Table 5.9 is 0.679 therefore, it is acceptable.
- The model with the higher PCFI is better and in Table 5.9 it is 0.693.
- In Table 5.9 PCLOSE is 0.777 which is now more than 0.05, RMSEA is 0.037 which is less than 0.05 therefore, the hypothesized structural model (Figure 5.5) is confirmed as it indicates all good fits.

Table 5. 9 Structural model fit summary

CMIN

Model	CMIN	DF	P	CMIN/DF
Default model	58.560	46	.101	1.273

RMR, GFI

Model	RMR	GFI	AGFI	PGFI
Default model	.044	.954	.922	.563

Baseline Comparisons

Model	NFI	RFI	IFI	TLI	CFI
Default model	.974	.962	.994	.992	.994

Parsimony-Adjusted Measures

Model	PRATIO	PNFI	PCFI
Default model	.697	.679	.693

RMSEA

Model	RMSEA	LO 90	HI 90	PCLOSE
Default model	.037	.000	.063	.777

After several attempts it has been revealed that the model shown in Figure 5.5 is the best conceptualised structural model. Even though the structural model had been designed based on other existing research findings, the interrelationships are rejected with the statistical significance level of $p<0.05$ in this research findings. The GOF indices for the structural model presented in Table 5.10 represent a perfect fit except for RMSEA which is 0.037, and it is below the minimum threshold of 0.05. The GOF indices for best fitting structural model seem acceptable, as shown in Table 5.10.

Table 5. 10 Summary of GOF results for the best fitting structural model

Goodness-of -fit (GOF) measures	Recommended level of GOF measures	Best fitting structural model
CMIN/DF	1 (very good) - 2 (threshold)	1.273
Root mean sq. Error of approx. (RMSEA)	>0.05 (very good) - 0.1 (threshold)	0.037
Root mean sq. Residual (RMR)	0 - 1 (Smaller values = better fit)	0.044
Goodness-of fit index (GFI)	0 (no fit) - 1 (perfect fit)	0.954
Comparative-fit index (CFI)	0 (no fit) - 1 (perfect fit)	0.994
Incremental-fit index (IFI)	0 (no fit) - 1 (perfect fit)	0.994
Tucker-Lewis index (TLI)	0 (no fit) - 1 (perfect fit)	0.992

5.4 HYPOTHESIS CONFIRMATION

In this Chapter, the interrelationships among different variables such as occupant environmental Attitude, Knowledge and Behaviour (AKB) had been investigated using SEM technique. The results indicate that there is a significant interrelationship between latent variables and their measured/ observed variables, but the interrelationships among latent/ unobserved variables were not significant which means occupants with good attitude do not necessarily behave in an environmentally friendly manner.

Although measurement model (Figure 5.4) and structural model (Figure 5.5) are verified as good fit models but these models were achieved after elimination of observed variables related to electricity and water consumption, which can interpret the fact that occupant environmental behaviour is not in line with design intent and only recycling behaviour seems to be acceptable indicating a good fit model. This finding confirms the hypothesis of this study provided in Chapter 1 which stated: *"the occupants of LEED-certified buildings are not knowledgeable and motivated to behave environmentally-friendly",* by showing insignificant interrelationship between latent variables AKB. Therefore, LEED certification needs to include occupant behaviour as currently the certification process and organisation does not have any specific action plan to influence occupant environmental behaviour, because it was found that there is no apparent attention paid to, or concern expressed over occupant behaviour.

It is accepted that today it is quite possible to produce an eco-friendly green building, however, it is also a priority need to adopt practices such as Soft Landings discussed in Chapter 2 in order to have industry professionals involved to educate the occupants to alter their behaviour in an environmentally-friendly fashion in order to achieve the potential energy savings in their buildings.

The best fitting structural model (Figure 5.5) showed that there is some interrelationship between knowledge and attitude, while both factors can affect behaviour, although these interrelationships are not very significant. This Chapter findings present a logical guide and a good fitting structural model (Figure 5.5), although without significant interrelationships between AKB, that can form the basis of a developed BOEB model – Stage 1 (Figure 6.1). This idea is explained in detail in Chapter 6.

CHAPTER 6 - BOEB MODEL DEVELOPMENT

6.1 INTRODUCTION

This research study highlighted the need for the process with inclusion of motivational factors to improve and alter building occupant environmental behaviour. The hypothesis is confirmed indicating lack of knowledge and motivation for occupants to behave in an environmentally-friendly fashion. The research has therefore proposed that building occupant environmental behaviour (BOEB) model to be developed to fulfill the aim of this research. The following sections detail the development of BOEB model.

6.2 SIMPLIFIED STRUCTURAL MODEL

Figure 6.1 presents a simplified version of the best fitting SEM model (Figure 5.5) which shows a two-way interrelationship between attitude and knowledge, one-way interrelationship between attitude and behaviour, and one-way interrelationship between knowledge and behaviour.

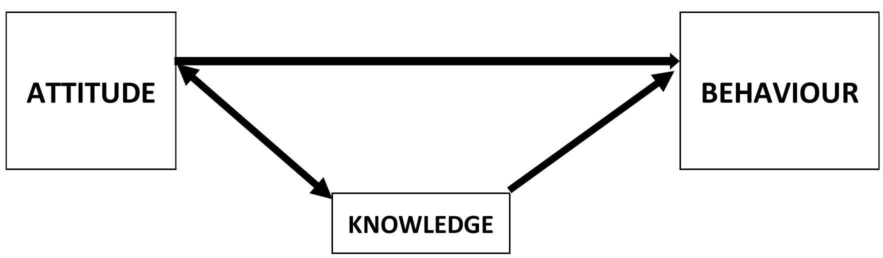

Figure 6. 1 Developed BOEB model – Stage 1 (Simplified version of Figure 5.5)

6.3 DEVELOPED BOEB MODEL

The best fitting SEM model is confirmed as a good model fit, but it does not show either attitude or knowledge making a significant impact on behaviour. There is a need for a process that influences and improves building occupant environmental behaviour (BOEB) through motivational factors. The developed BOEB model – Stage 1 (Figure 6.1) was combined with findings in Chapter 2 and Chapter 4 to include additional factors which can influence occupants with a view to change their behaviour. Occupants behave in different ways in different situations considered as additional factor found in the interview part of this research shown as **Drivers** in Figure 6.2. It is important to understand how these **Drivers** can bring **Needs** to occupants. **Drivers** are all those classified as social, psychological, and physiological situations. For example, physiological discomfort caused by extreme hot weather in the UAE can bring **Needs** to occupants to cool down themselves, and they respond to that in different ways. Some occupants might reduce layers while others might have the desire to turn on or increase the cooling system. All these different behaviours are shown as **Actions** in Figure 6.2.

The developed BOEB model stages (Stage 2 – Stage 8) are explained in detail based on number coding shown in Figures 6.2 to 6.8 as follow:

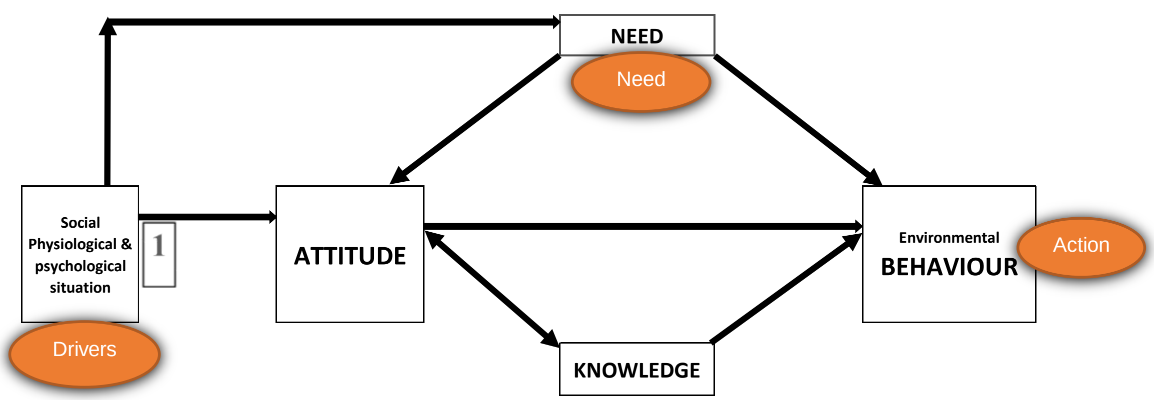

Figure 6. 2 Developed BOEB model – Stage 2

6.3.1 SOCIAL, PHYSIOLOGICAL AND PSYCHOLOGICAL SITUATIONS, NEEDS, AND ATTITUDES (NO.1)

Acceptable and comfortable situations socially, physiologically, and psychologically are **Drivers** which can bring needs to occupants, causing them to behave in certain ways with certain actions (Turner & Hong, 2013). People have different types of needs resulting from their physiological and psychological conditions. The combination of these needs and the way people behave can be transferred to social norms and as a result to become their attitude and beliefs. Once physiological needs are satisfied, people tend to behave in a more environmentally-friendly manner. Needs theories try to identify some internal factors which can motivate occupant behaviour while people are motivated by unfulfilled needs (Turner et al., 2013). For example, if occupants are dissatisfied with staying in a cool room at 18 degrees centigrade, they might increase the heating system. In doing so, they will fulfill the need for comfort level, which may involve wearing fewer clothes instead of adding more layers to keep themselves warm.

The expectancy-value formulation of attitudes based on Fishbein and Ajzen (1975) mentions that each occupant has certain beliefs about an object and knowledge of that object. These beliefs are evaluated on a favourableness dimension, they concluded that the result of evaluations, multiplied by beliefs, constitutes the personal attitude. Similarly, in the developed BOEB model – Stage 2 (Figure 6.2) social norms and attitude constitute the component affecting behavioural intention. As suggested, attitudes do not necessarily cause behaviour; a conclusion based on evidence from the literature review as well as findings from Chapters 4 and 5 findings. Attitudes are related to behaviour in a way that changing occupant attitudes should lead to the desired behaviour but that didn't happen in this research study's findings in Chapter 4, this was due to the fact that the majority of those occupants who had positive approach towards environmental attitude didn't behave in an environmentally-friendly fashion.

Van Raaij and Verhallen (1983) believed that if we change behaviours in a more environmentally-friendly direction, we may expect that occupants develop environmental attitudes but the reverse is not always true, however, such impact from behaviour on attitude is not shown on their model in Chapter 2, Figure 2.7. The assumption is that occupants aim at maintaining stasis in their environmental behaviours. Research findings in Chapter 4 showed that many occupants claim positive environmental attitudes and awareness but have not yet translated those beliefs and attitude to their environmental behaviour. This dissonant behaviour is in line with the statement from Geller et al. (1979) who concluded that educational efforts to change attitudes in an energy conserving direction are not as effective as action-oriented efforts to change behaviour.

There are several factors affecting environmental attitudes, such as: i) environment and energy concerns, ii) health and comfort levels and iii) price concerns. These factors also influence environmental behaviour significantly. Knowledge is important in order to fulfill the needs with regards to these factors because occupants can become aware of their energy use, energy price as well as comfortable and healthy lifestyle while behaving environmentally-friendly.

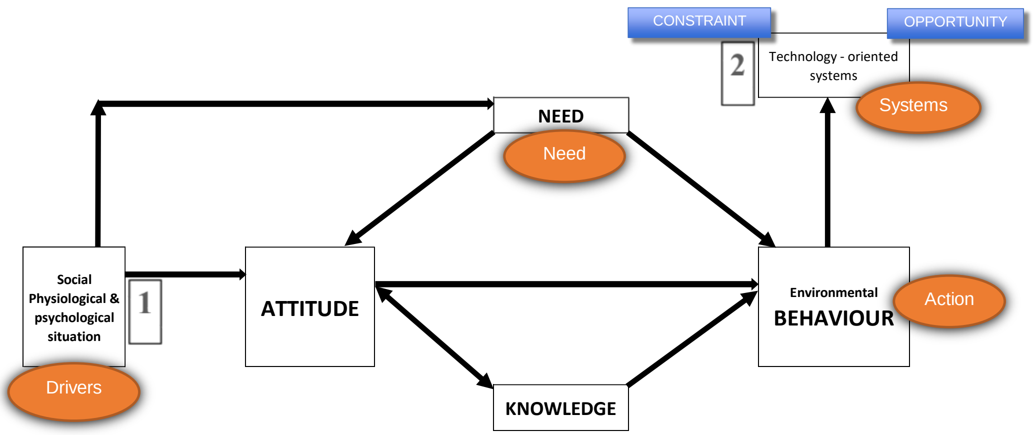

Figure 6. 3 Developed BOEB model – Stage 3

6.3.2 BUILDING TECHNOLOGY-ORIENTED SYSTEMS (NO.2)

The technology-oriented systems shown in the developed BOEB model – Stage 3 (Figure 6.3) are considered as both **Opportunity** and **Constraint** for occupants. Technologies required or suggested by LEED-certification and designers bring more of the capabilities for buildings and opportunities for the occupants if those systems are user-friendly and occupants are trained on how to operate them. Until the building is not capable while equipped with user-friendly equipment, nobody can expect occupants to behave environmentally-friendly. Therefore, capable buildings can bring a great opportunity for occupants but if they are not user-friendly as claimed by some occupants in interview in Chapter 4 of this study, not only they are not opportunities, but they bring constrains to occupant daily life. As a result, technology-oriented and user-friendly systems had been added to Figure 6.3 as a necessary factor in LEED-certified buildings, which can influence occupant behaviour positively.

On the other hand, these systems and equipment can influence their behaviour negatively if those occupants do not know how to operate them (constraint). Through such systems it is possible to analyse the energy consumption and use it as feedback to occupants in order to create an effective socio-cultural environment (**Motivation A**) that will be discussed later in this Chapter in detail.

Non-human opportunities can be categorised into two parts: i) contextual and ii) physical-environmental. Contextual capabilities are building's systems and examples of physical-environmental capabilities are noise, temperature, humidity, and lighting. In the developed BOEB model 'opportunities' are shown in the home's characteristic, appliances and technology-oriented systems. These factors can be considered as the building's capabilities which can help occupants to improve their level of comfort and satisfaction. Occupant satisfaction is entirely in relation with their knowledge and understanding of those technologies, because if those systems are not user-friendly then they are not opportunities anymore and can definitely bring constraints and difficulties for their occupants and therefore, occupants will not behave in an 'as-designed' way desired by professionals and designers, especially when they have not been appropriately educated or trained.

Both building design and technology-oriented systems constitute important contributions to energy conservation (Turner & Hong, 2013; Van Raaij & Verhallen, 1983). These user-friendly technology-oriented systems can influence the environmental behaviour of occupants and the performance of a building which is mainly controlled by its occupants. The control methods of the systems are important when considering the energy performance of the building; particularly when the ease of controlling such building systems can change the environmental behaviour of their occupants. Occupant behaviour and home characteristics are more important determinants of energy consumption than attitudes (Verhallen and Van Raaij, 1981), such statement is a perception that is in line with the findings from this research, as presented in Chapter 4, that the occupants made known attitudes that were considerate about global warming and climate change but they did not have excellent environmental behaviour.

Technology-oriented systems are important parts of all models and frameworks that were reviewed in Chapter 2. Turner & Hong (2013) mentioned it as systems in DNAS framework while drivers bring needs to occupants and push them towards certain actions on their systems. Such systems should be well-designed and simulated based on realistic occupant needs and they should be user-friendly systems to be considered as opportunities. It is a crucial part of the BOEB model to enhance and modify technology-oriented and user-friendly systems based on occupant needs and comfort continuously throughout the process of improving building occupant environmental behaviour.

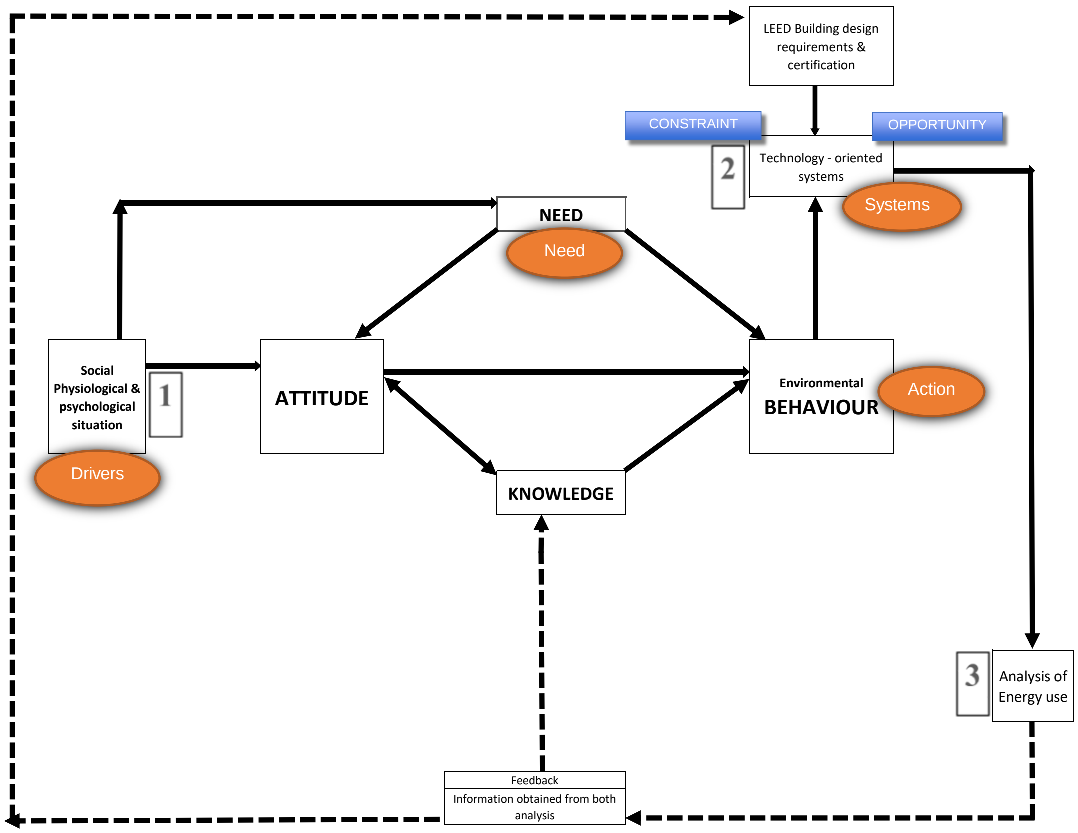

Figure 6. 4 Developed BOEB model – Stage 4

6.3.3 ENERGY USE AND ANALYSIS OF THE ENERGY USE (NO.3)

Analysis of energy use are dependent variables in the developed BOEB model – Stage 4 (Figure 6.4) which can be extracted from technology-oriented systems designed in buildings. Energy use is influenced by environmental behaviour and efficiency of the systems. It can be an effective way of providing feedback to occupants about the outcome of their environmental behaviour. The model contains **Feedback** from analysis of energy use in order to enhance knowledge and to develop or identify financial incentives. Janda (2011) believed that the feedback is very helpful therefore, better information and feedback systems will result in better usage patterns. Based on the findings from this study and also on the research by Van Raaij & Verhallen (1983), the shorter the feedback period the more effective the feedback information will be, e.g. in Chapter 4 some of the occupants mentioned that they need to have fast feedback period to know about the outcome of their action and if they behaved environmentally-friendly then possibly receive cash back on their savings because they are not sure how long they might live in the building.

For optimal effect feedback needs to be related to a specific activity and enforced by decision makers and authorities to use it for a bigger purpose as motivation which will be discussed in detail later in this Chapter. Feedback information on energy costs is more effective in reducing energy consumption than general information on energy conservation, or knowledge supplied through information prompts (Van Raaij & Verhallen, 1983), this can be achieved by designing and installing smart monitoring systems which can bring ease to the analysis of energy use.

Feedback information raises awareness among occupants about the quantity and costs of the energy they consume. If the occupants are enabled to relate this information to their environmental behaviour evaluation, a learning process and behavioural change towards an energy-use reduction lifestyle can happen (Van Raaij and Verhallen, 1983). In the developed BOEB model – Stage 4 (Figure 6.4) a feedback loop is added which is represented by a dotted line coming from the analysis of energy use. This feedback loop can be implemented and monitored by industry professionals as after care service for Post Occupancy Evaluations (POEs) process. The practices of Soft Landings discussed in Chapter 2, can reinforce such feedback loop.

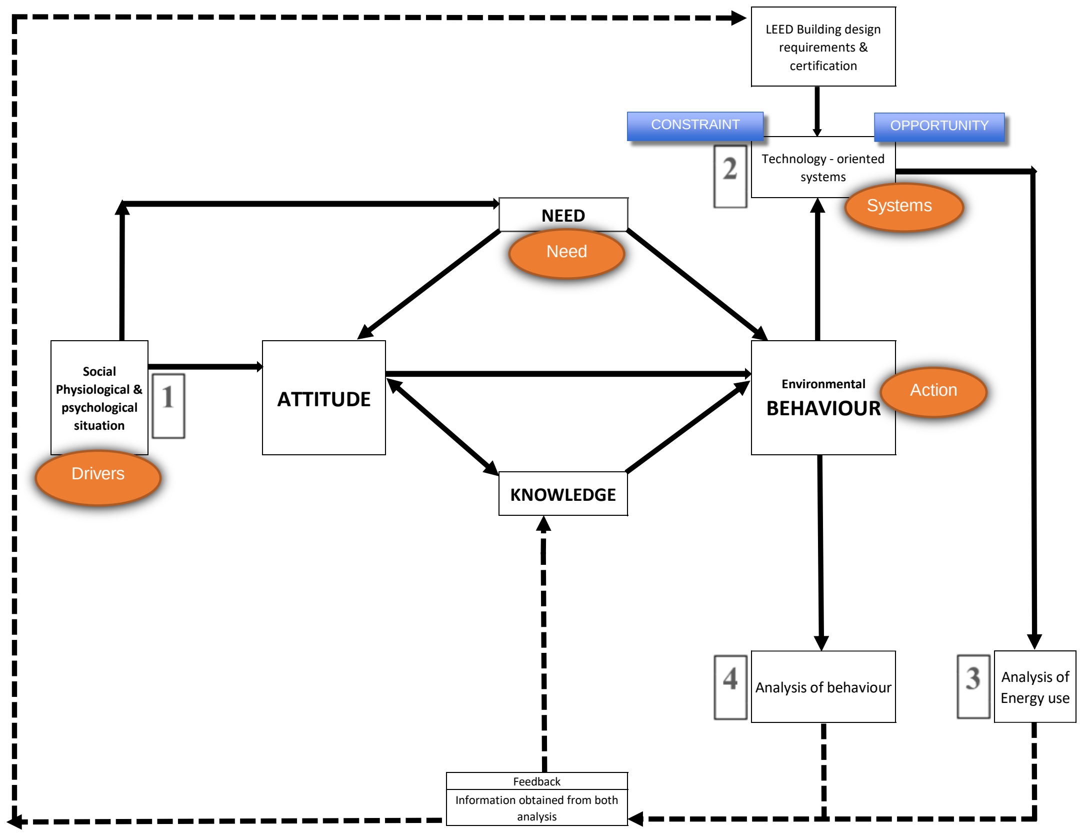

Figure 6. 5 Developed BOEB model – Stage 5

6.3.4 BEHAVIOUR AND ANALYSIS OF THE BEHAVIOUR (NO.4)

Environmental behaviours in this study are dependent variables and focus on day-to-day use of home appliances, systems, water, and electricity, as well as recycling habits and transportation, all of which are considered as behavioural evaluation. If such information is directed to 'knowledge', as shown by the dotted line in Figure 6.5, then the feedback from the analysis of the environmental behaviour, as claimed by occupants during the interviews in Chapter 4, can inform and encourage them to behave environmentally-friendly.

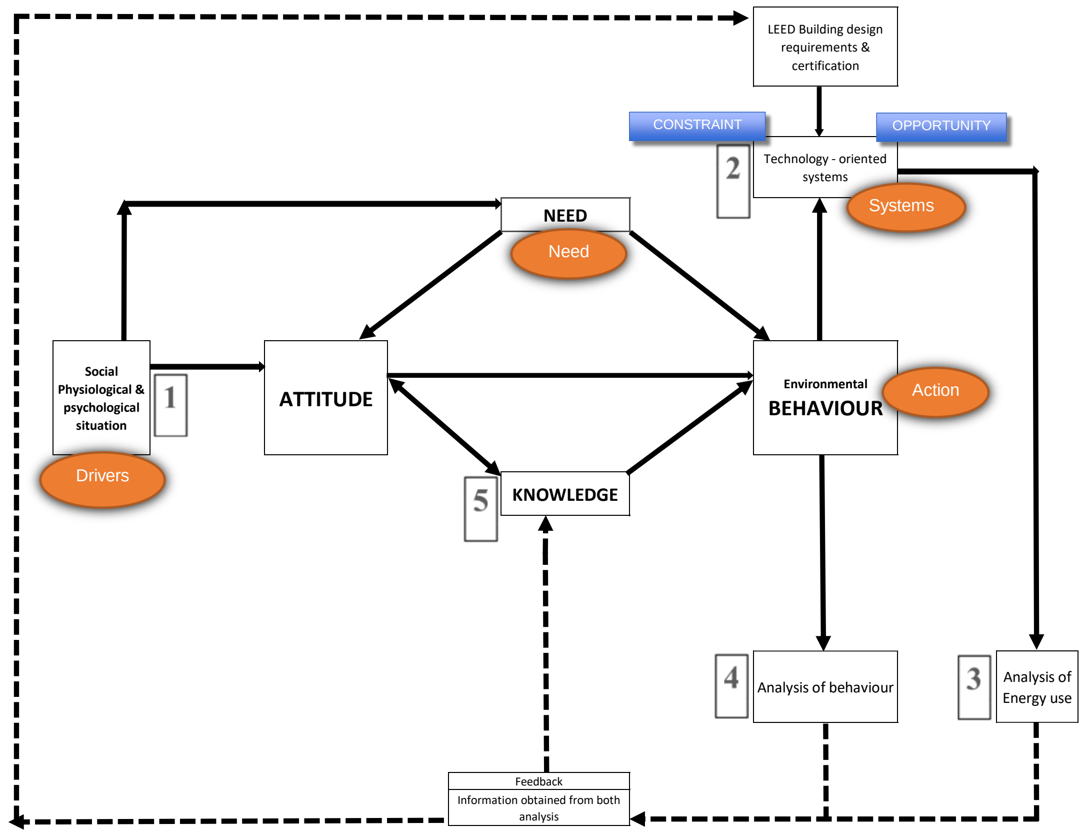

Figure 6. 6 Developed BOEB model – Stage 6

6.3.5 KNOWLEDGE (NO.5)

In the developed BOEB model, knowledge has a two-way interrelationship with attitude, although, it can significantly change behaviour prior to attitude change. Based on the findings by Van Raaij and Verhallen (1983) knowledge as an effective feedback about energy use and behaviour evaluation, can either change behaviour directly, considered as the shorter path option, or by influencing attitudes first which can then change behaviour considered as a longer path.

The findings of this study show no significant interrelationship between AKB therefore, there should be further concentration on the process to motivate building occupants towards environmentally-friendly behaviour which will be discussed in detail in the next section.

Such knowledge can then change occupant social norms by creating socio-cultural environment as **Motivation A** in Figure 6.7, and mainly if integrated with information about cost and cash incentives then the relevant knowledge is triggering **Motivation B** (Figure 6.8) to influence environmental behaviour directly and fast.

Knowledge about behaviour analysis while raising awareness through effective feedback can create a positive socio-cultural environment **(Motivation A)**. In Chapter 4, the occupants confirmed that they care about their consumption and they want to become more knowledgeable about their energy use. On the other hand, some of the occupants mentioned that they do care about their energy bills and they have some monetary concerns and therefore, if they will be informed about possible cash incentives (**Motivation B**), they are more motivated to behave in an environmentally-friendly fashion.

Negative impact from lack of occupant knowledge and education was revealed in research findings in Chapter 4 as occupants mentioned that they are willing to be trained through workshops or paper guides in order to better understand their home's characteristics, appliances and technology-oriented systems. Such information can influence occupant behaviour positively while occupants can bring the best out of such systems. Therefore, continuous review on analysis of energy use can help to educate occupants and modify the systems by professionals towards designing more efficient and user-friendly systems.

The effectiveness of the feedback loop feeding the knowledge can be done through: a) self-monitoring, b) Occupant environmental behaviour analysis and evaluation, c) Analysing & judging occupant behaviour by their neighbours; this is obviously creating socio-cultural environment known as **Motivation A**, d) simplifying the procedure of analysis through BOs and professionals involvement and finally e) using all the information to review and if needed revise the technology design and efficiency for the buildings. Such knowledge can assure the designers and professionals about the efficiency of their design and simulation process.

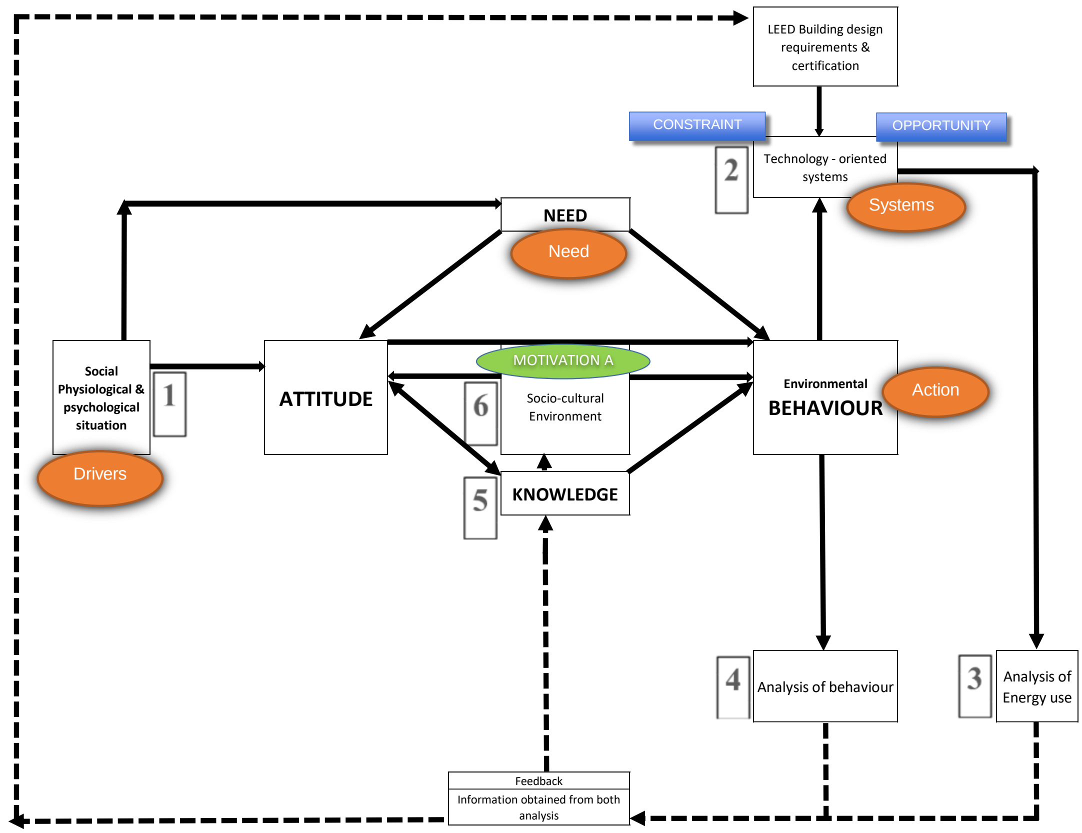

Figure 6. 7 Developed BOEB model – Stage 7

6.3.6 SOCIO-CULTURAL ENVIRONMENT (NO.6)

Creating a socio-cultural environment is considered as **Motivation A** in Figure 6.7 which is an effective factor to improve environmental behaviour. In the developed BOEB model – Stage 7 (Figure 6.7), **Motivation A** can be seen as a shorter path to influence occupant behaviour directly and as a longer path to change attitude which can eventually change behaviour overtime. Lifestyle is determined by socio-cultural factors and other personal factors such as habits, leisure, age, marital status, family size, income, and education. In a process of socialization and cultivation as well as in reference to other people, media, and socio-cultural environment, building occupants develop their life-styles and environmental behaviour. Lifestyle and behavioural routines are hard to alter or change and it is likely to be a gradual process over time.

In Chapter 4 of this study, it was shown that many participants claimed energy conscious attitudes but had not yet translated them into energy conscious and environmental behaviour. This anomaly was revealed in the lack of significant interrelationship between attitude and behaviour in Chapter 5. The case study presented earlier while putting bigger stickers on the occupant door who are leaving their lights on, confirmed the fact that socio-cultural environment is an effective motivational factor for people as it is socially undesirable for them to be seen as careless occupants. These concepts included in the socio-cultural environment named '**Motivation A**'. Knowledge and activities such as announcing occupants about their environmental behaviour can create the effective socio-cultural environment to influence occupant environmental behaviour.

Socio-cultural environments can also be improved by personal communication and mass media in order to overcome the way the information is provided about energy conservation (Van Raaij & Verhallen, 1983). These changes in behaviour can become part of a person's day-to-day practices and lifestyle.

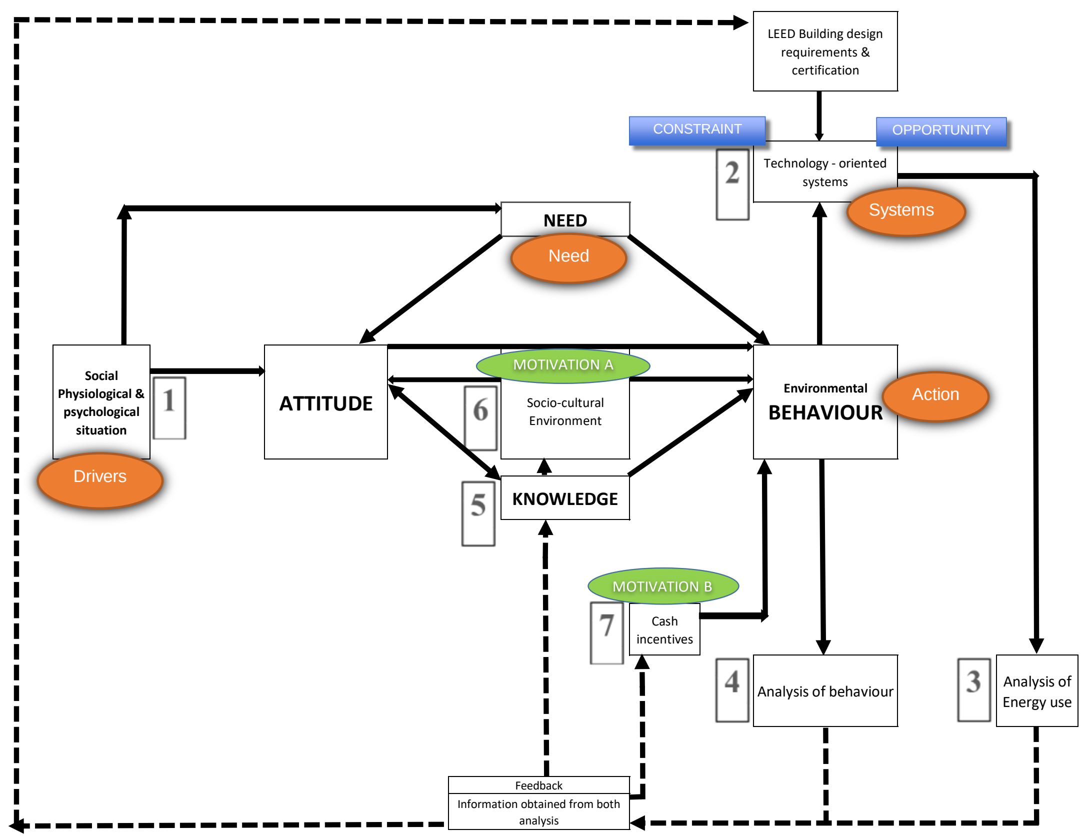

Figure 6. 8 Developed BOEB model – Stage 8

6.3.7 CASH INCENTIVES (NO.7)

The cash incentives are shown as **Motivation B**, considered as another shorter path to achieving the desired environmental behaviour change. Based on findings from survey responses and interviews presented in Chapter 4 (Table 4.22), this motivation factor has a huge impact on occupant environmental behaviour. Financial motivation is the most important factor that can improve participating occupant behaviour, pointing it towards sustainability. In order to improve occupant environmental behaviour, this study results confirmed that occupants should be motivated. In the developed BOEB model – Stage 8 (Figure 6.8), the cost-benefit trade-off has been placed as an effective motivational factor relating to environmental behaviour. This economical factor is an important construct for altering environmentally-friendly behaviour.

Cost benefits, the price of energy and social norms can play a significant role in energy consumption, and if combined with proper knowledge and feedback from the evaluation of their behaviour and energy use can strengthen its impact. Heberlein and Warriner (1983) concluded that attitude and knowledge have stronger impacts on behaviour than cost. However, the findings from the research study in Chapter 4, as well as the model from Van Raaij & Verhallen (1983) in Chapter 2 of this research study, suggested that financial incentives strongly motivate many occupants towards environmental behaviour change.

It should be noted that such an important variable as motivation is not shown on the models and frameworks that were reviewed in Chapter 2, even the DNAS framework offered by Turner & Hong (2013) didn’t include any motivation between Drivers, Needs, Actions and Systems. Most occupants do not want to scarify their comfort and change their life-styles, habits, and behavioural routines without solid motivation, especially when they have certain or specific needs.

6.4 CHAPTER SUMMARY

This Chapter has presented the process of proposing the developed BOEB model. The main purpose of this model was to collect the factors influencing LEED-certified building occupant environmental behaviour. This model provides researchers, professionals, policy makers and governmental authorities with an indication of motivational factors relevant to the occupant environmental behaviour and their energy use.

We may change behaviour directly without changing attitudes first and even behaviour can influence attitude in many cases. However, attitude change can also lead to behavioural change over a longer time span, because most occupants are not willing to change their preferred lifestyles; a situation which can be clearly seen in the developed BOEB model.

The motivational factors extracted from the research results in Chapter 4, as well as from the literature review in Chapter 2 are incorporated into the model which are shown by two different green oval shapes such as: i) socio-cultural environment considered as **Motivation A** (No.6 in Figure 6.7) and ii) financial incentives and cost benefit trade-off as **Motivation B** (No.7 in Figure 6.8).

Regular behaviour and energy use analysis by understanding the interrelationship between them, as well as comparing them with other occupant behaviour, can make the feedback process increasingly effective by creating a positive socio-cultural environment (**Motivation A**). Such feedback can also increase building occupant knowledge of energy and cash incentives (**Motivation B**), to improve their environmental behaviour to narrow the performance gap between design and operational outcomes.

Van Raaij and Verhallen (1983) mentioned that the intervening constructs of *attitudes* and *behaviour* lead to the following hypothetical conditional roles. These positive attitude and norms toward energy savings which were shown in Van Raaij and Verhallen (1983) framework (Figure 2.7) combined with different factors found in Chapter 4 of this study and other findings in the Chapter 2 literature review are summarised as follow:

- If occupants have the physical and/or financial possibility to perform energy-conscious behaviour (**Drivers & Needs**)

- If occupants accept their responsibility for energy conservation (**Attitude**)

- If occupants have enough knowledge about the energy consequences of their behaviour (**Knowledge & Feedback & Motivation A**)

- If occupants perceive their contribution to energy conservation to be effective (**Knowledge & Feedback & Motivation A**)

- If the economic and behavioural cost-benefits for energy conservation are positive (**Motivation B**)

As mentioned, energy-sensitive attitudes do not necessarily cause environmentally-friendly behaviour therefore, other factors such as energy knowledge which can led to having effective socio-cultural environment (**Motivation A**) and cash incentives (**Motivation B**) may create great motivations for occupants to behave in an environmentally-friendly manner.

Finally, inclusion of occupant behaviour by providing a means of earning credits/ points in LEED certification process while considering the factors included in the developed BOEB model can promote environmentally-friendly behaviour among occupants.

CHAPTER 7 - BOEB MODEL VALIDATION

7.1 INTRODUCTION

In this part of the research the developed BOEB model – Stage 8 (Figure 6.8) was validated by total of 6 validators; two academic researchers, one industry professional and three building operators (BOs) who were involved in the process of LEED-certified buildings design, construction and operation.

7.2 BOEB MODEL VALIDATION AIM AND OBJECTIVES

The aim of the developed BOEB model – Stage 8 validation is to determine its appropriateness and applicability during the development and maintenance of green buildings. Three themes are:

1. To assess the effectiveness and applicability of the BOEB model for professionals to gain knowledge in order to improve occupant behaviour and to educate them.
2. To assess any barriers preventing the implementation of the BOEB model.
3. To find out the best recommendations from researchers, industry professionals and building operators in order to improve the BOEB model.

7.3 METHOD OF VALIDATION

Initially it was decided to contact the same BOs in the UAE who participated in the interviews. Unfortunately, only one of them was accessible therefore, one industry professional in Dubai and two BOs in Toronto city were selected. In addition to that, two academic researchers with similar areas of interest and experience to this research area accepted to review and validate the model. This selection was informed by a reason which was to have variety of opinions in both developed and developing countries on LEED process and occupant environmental behaviour improvements strategies. This approach enabled the researcher to review the applicability of such model in the region other than the UAE. Six validation interviews were conducted. Details of the professionals and researchers involved during the validation process are presented in Table 7.1. The validator’s names are not included in this table in order to keep them anonymous in line with ethical considerations given to them. The two exceptions who accepted to be named are:

- Dr. Beth Savan, associate professor, and researcher at University of Toronto-Canada,
- Dr. Issam Ezzedine, Senior Architect at the NEB consulting firm in Dubai-UAE.

Table 7.1 shows the minimum years of experience of the industry professional and BOs in designing and operating similar buildings and academic researchers in studying and researching similar topics to this study. Table 7.1 also shows the location of each validator. It was very valuable to the researcher to have a combination providing insights from the UAE and the North American professionals. The latter group represents individuals who are also knowledgeable in terms of advanced energy conservation practices and familiar with the LEED certification process.

Table 7. 1 Background information of the validators

Validators No	Job Title	Location	Years of Experience
1	Building Operator1	Dubai- UAE	9
2	Professional-Dr. Issam	Dubai- UAE	20
3	Building Operator2	Toronto- Canada	12
4	Building Operator3	Toronto- Canada	15
5	Researcher1-Dr. Savan	Toronto- Canada	5
6	Researcher2	Toronto- Canada	5

The validation process was carried out using an interview approach during face-to-face and Skype meetings. Each validation session was designed to last 60-90 minutes. First there was a presentation to the validators summarising the overall research resulted in the development of the BOEB model including the aim and objectives of the research methodology. Then, the developed BOEB model was presented to the experts for their review. Finally, the following interview questions were asked. Interviews were recorded by written note since the validators declined to be voice recorded.

7.4 RESULTS OF VALIDATION

The interview results are analysed and presented under three main themes as follow:

7.4.1 THEME 1: EFFECTIVENESS AND APPLICABILITY OF THE BOEB MODEL

The validators were asked about the effectiveness and applicability of the developed BOEB model (Figure 6.8). All of them agreed that the model provided a logical process for improving building occupant environmental behaviour and attitude, especially through some of the factors which were motivating them. Moreover, they all agreed that the motivational factors are important parts of this model as those factors were considered in some other models, such as the behavioural change model by Van Raaij & Verhallen (1983). The issue of cash incentives was another factor that the validators liked in terms of being a very strong motivator.

It was also agreed that technology-oriented systems are useful in terms of energy use analysis and conservation while there are also some comments which will be discussed later under the recommendation theme.

Dr. Beth Savan agreed on research finding in terms of insignificant interrelationships between Attitude, Knowledge and Behaviour (AKB) in Chapter 5. Moreover, the connectivity of knowledge to both attitude and behaviour, while it might change one without any changes on the other one, stood out as the most liked feature of the developed BOEB model for this researcher. Therefore, she agreed that behaviour can be changed without changes happening on attitude first and this process can become part of people attitude and lifestyle over time. Therefore, motivational factors can be very effective.

All validators agreed about the usefulness of the developed BOEB model. They agreed that the model should be considered within the policy and procedures in LEED-certification process and building management system. They mentioned developed BOEB model is a continuous educational and feedback process especially in the UAE with many of its temporary residents and professionals.

They also believed that the feedback loop can help occupants to become aware of the result of their behaviour and energy use, as well it can be considered as an effective parameter to inform designers and policy makers about the outcome of the systems they designed, whether they are well-designed and well-simulated at design stage.

The important consideration in terms of the usefulness and applicability of the model was mentioned by Dr. Issam Ezzedine: *"the model should be formulated to consider several levels of effectiveness/ usefulness such as occupant Reaction, Learning, Behavior and then synthesized Results. You want occupants to feel that the new model/ system is vital and valuable, so training is mandatory. Measuring how engaged they were, how actively they contributed, and how they reacted to the training helps them to understand how well they received it. It also enables them to make improvements to future programs, by identifying important topics that might have been missing*." Therefore, the effective and well-planned training as well as involvement of professionals are essential parts of the BOEB model application and effectiveness.

7.4.2 THEME 2: BARRIERS TO THE IMPLEMENTATION OF THE BOEB MODEL

The validators mentioned the following barriers to the deployment of the model, their opinions were similar in some of the following therefore, the answers were categorized in main six barriers:

Barrier 1. The main party who seem to be the most effective one in terms of implementation is LEED, the question might raise that 'how quick LEED decision makers can digest/ accept the proposed BOEB model in order to act to become part of the process and policy' and 'how quick they can bring post occupancy as part of their certification process.' If they don't adopt such process, then it seems to be challenging to deploy the model if such process won't be part of the requirement set by LEED.

Barrier 2. The building managers and occupants may not see the result of the developed BOEB model process, as it takes time to educate people in order to change their behaviour and as a result their attitudes. The time-consuming process of going through feedback and informing people might cause a lack of interest in the model's application too. It will likely be costly and time-consuming to implement BOEB model.

Barrier 3. The interview part with building occupants and operators seems to be challenging as part of the Post Occupancy Evaluations (POEs) process. This is also confirmed by the response rate of 13.8% in interview part with occupants in this research study while 72 occupants were contacted and only 10 occupants accepted to be interviewed. The model may not be vital or practical to all organizations or communities, especially when the level of trainings varies, and as well the lack of acceptance to the process specially the POEs part of the model for occupants.

Barrier 4. Lack of interest from authorities in terms of motivational factors such as cash incentive might result in ignorance of building occupants in terms of energy usage reduction. BOs, occupants, and industry professionals might not be sufficiently self-motivated or responsible to implement the developed BOEB model procedures as it is time consuming and costly.

Barrier 5. Most likely, occupants, LEED smart systems and organization decision-makers change in different ways, and these changes will have impact on outcomes, and as well the training procedures, which will lead to new types of behaviors and reactions.

Barrier 6. The biggest challenge as mentioned in the previous section for effectiveness of the BOEB model application will be to identify which benefits, outcomes, and final results are most closely linked to the training, and to come up with an effective way to measure these outcomes in the long term.

In conclusion, the barriers are centred on the issues around: a) cost, b) time, c) responsibility, d) policies and e) training. It is obvious that some people might have negative reactions driven by one or all the issues identified. Recommendations in the next section might ease the situation in order to overcome the raised barriers and to implement the developed BOEB model effectively.

7.4.3 THEME 3: RECOMMENDATIONS TO IMPROVE THE BOEB MODEL

The validators recommended the following to ease the implementation of the model, which led to the modification of the developed BOEB model. The new version incorporating the recommendations, presented in the next section in Figure 7.1, can be seen as the final BOEB model.

"There must be LEED certification policies and credits to help professionals and building operators to implement such models. The model will need to be published and shared with LEED decision-makers and governmental senior level actors who will facilitate to integrate the model in their policies and regulations guidelines/ manuals." BO 1 from the UAE.

"The model should be engaged in both the academic and industry sectors. The findings should be presented academically in many LEED conferences and sustainability educational events. Different boxes in this model should be getting credits or required points for LEED recertification. High level conferences should be called by inviting decision-makers to share with them how this model can positively be efficient on occupants and the building energy consumption. Architects and engineers are key professionals that can help to adopt the idea of the developed BOEB model." Industry professional (Dr. Issam Ezzedine) from the UAE.

"There should be some funding available in order to help occupants who need support from the governmental authorities in the UAE similar to what we have as subsidies here in Canada." BOs 2 and 3 from Canada.

*"Attitude and knowledge don't necessarily predict behaviour while there are many other factors such as comfort level and motivation that will affect behaviour faster. There should be more concentration on those parameters to change behaviour, such change can even change lifestyle, beliefs and attitude. The findings in Chapter 5 of this study revealed that there is no significant interrelationship between AKB, why not to fade the interrelationship between Attitude and knowledge and their impact on environmental behaviour (cause and effect part of the model). The concentration can then become mainly on the process which can improve building occupant environmental behaviour (BOEB) through motivational factors (**Motivation A & Motivation B**) only."* Researcher 1 (Dr. Beth Savan) from Canada.

The above statement is in line with Van Raaij and Verhallen (1983) belief that if we improve energy behaviour, we can expect that occupants improve their energy attitudes.

"There is no need to indicate systems as opportunities and constraints on the model." Researcher 2 from Canada.

7.5 FINAL BOEB MODEL

Based on the following feedback summary from experts Figure 7.1 represents the final BOEB model. This model can be utilised by the LEED-certification process, as part of their framework to include occupant behaviour and can be monitored through practices similar to Soft Landings:

- All researchers and BOs as well as an industry professional believed that knowledge can better influence behaviour through motivational factors. As a result, knowledge should either: i) create socio-cultural environment (**Motivation A**) while occupants are self-monitoring or monitoring each other while they can have partnership in their community, and, ii) provide information to occupants about cash incentives involved in their environmental behaviour improvement process (**Motivation B**) by which people can be rewarded.
- Academic researcher Dr. Beth Savan found the same insignificant interrelationship between attitude and behaviour in many cases in her studies. She, as well as all the other validators, confirmed that occupants should be motivated to change their behaviour which can become their lifestyle and beliefs. As a result, behaviour change can influence attitude and lifestyle too therefore, there is no need of showing such cause-and-effect interrelationship as one can influence the other.
- There is no need for further indicators 'opportunity' and 'constraints', although technology-oriented systems can bring both opportunities and constraints.
- They all agreed that the model provided a logical process, including knowledge through continuous and effective feedback loop, which can improve occupant environmental behaviour, however, the concentration on the process should become clearer.
- Some of the barriers to implementing the developed BOEB model were centered on the analysis and feedback process being perceived as a time-consuming and costly procedure which needed an educated team to manage and monitor such a process. Therefore, the feedback should be used by LEED policy makers and industry professionals to influence their future decisions regarding their certification process and building systems.
- Lack of support from authorities and BOs can reduce the level of effectiveness of such a model and therefore, there should be a close collaboration between green agencies such as LEED and the governmental authorities.

Figure 7.1 was again reviewed by the six validators and they all agreed that the following final BOEB model is more understandable and simpler to use as part of LEED-certification process.

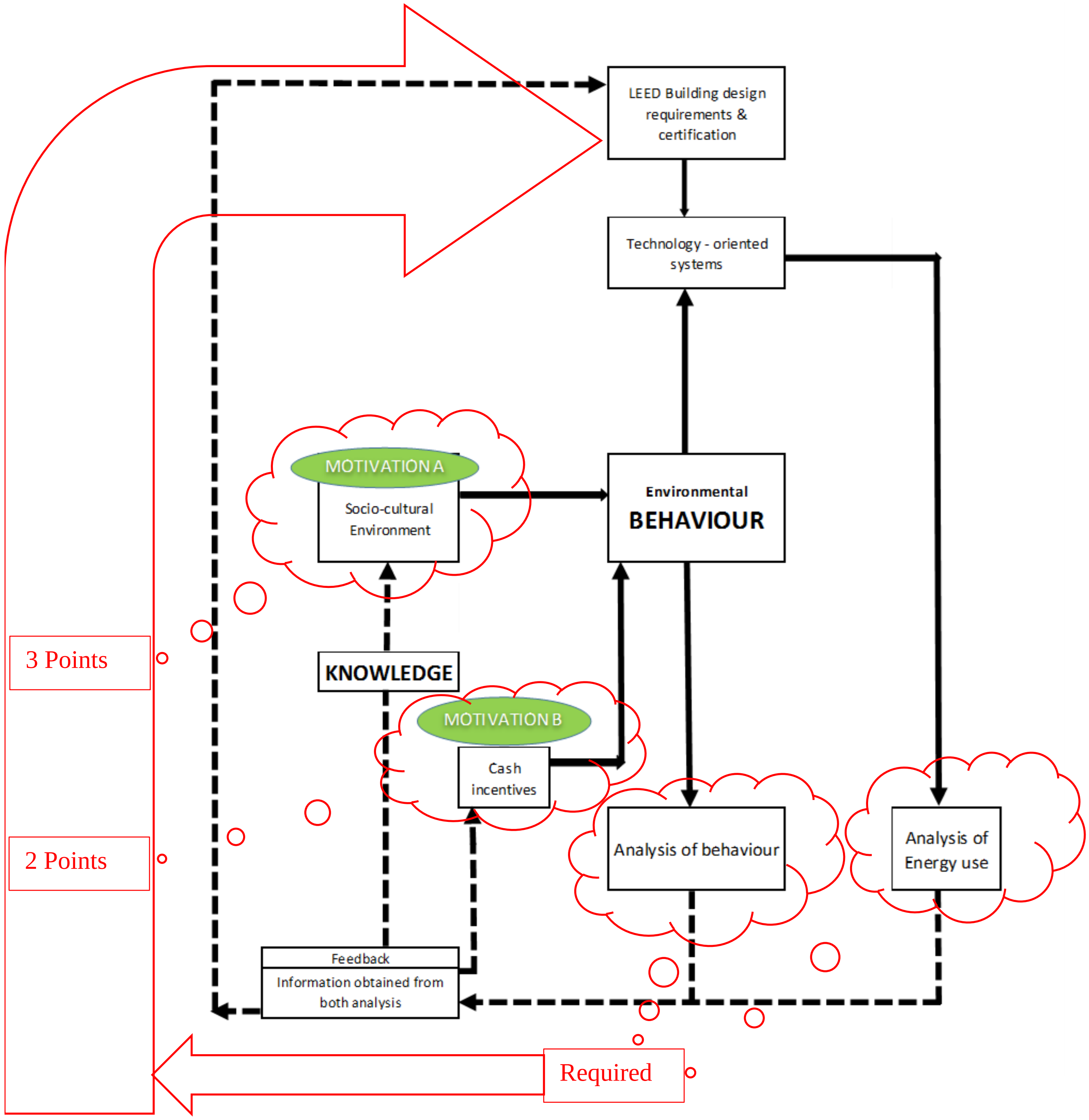

Figure 7. 1 Final BOEB model

7.6 FINAL BOEB MODEL AND LEED-CERTIFICATION

Findings from the validation process confirmed that the final BOEB model (Figure 7.1) is valid and has credibility after final revision by validators. There are certain potential implementation barriers such as time, cost, and education. Therefore, there should be funding to facilitate the process of implementation and monitoring by professionals. The final BOEB model is also able to serve the intended purpose of improving occupant environmental behaviour and reducing energy consumption if it becomes part of LEED certification process and especially the core part of **'After Occupancy Care'** during recommissioning phase as shown in Figure 7.1. High outcome from POE and deployment of the final BOEB model can be considered as a new category for inclusion in the post-occupancy phase of the LEED certification process.

The overall findings and feedback from the implementation of such a model can also give an idea to industry professionals, particularly LEED decision makers, to review and modify the current building design requirements and certification standards and to adopt soft landings practices. Equally the model can inform those same professionals about the effectiveness of proposed design requirements and user-friendly systems specifically, if the building can be certified for its post-occupancy and recommissioning phase. Therefore, LEED can influence the choice of the home characteristics and appliances, which can have a huge impact on occupant environmental behaviour. Nevertheless, these technology-oriented systems are not enough to gain as designed energy use while occupants must be motivated, educated, and knowledgeable about how to behave within LEED-certified buildings. Therefore, occupant environmental behaviour and **'After Occupancy Care'** should be considered in LEED certification process and possibility to assign points and credits to this important factor affecting building energy use.

To fully address this task, either an existing professional group should educate the occupants, or a new professional group should be created to deliver this important role. If the LEED-certification process adopts the final BOEB model within its practices and certification process, it will be including occupant behaviour similar to the BREEAM summary of changes in 2018. These changes included the addition of occupant behaviour and POE under the 'management' category. Two major points were: i) during *'commissioning and hand over'*, the building's 'user guides' and training should be provided to occupants and building operators, and ii) *'after care'* while there should be new requirement for funds to be committed to achieving POE. This part of the BREEAM 2018 process, while including occupant usage and behaviour, needs to be covered by the LEED-certification process, with intensive monitoring and management tools to suit a well-planned and well-designed model.

Therefore, a new category should be added to LEED certification process as follow:

After Occupancy Care

➢ POE and analysis of behaviour	Required
➢ Analysis of energy use	Required
➢ Self and others monitoring (Socio-cultural environment, **Motivation A**)	3 Point
➢ Cash reward and punishment (**Motivation B**)	2 Points

This research finding proposes that LEED-certification decision makers should have closer collaboration with governmental authorities and industry professionals in order to raise funds for POEs to obtain and evaluate the feedback about occupant environmental behaviour and energy use. Awareness will be raised through feedback, education, and monitoring, which is as a result creating a positive socio-cultural environment; shown in the final BOEB model as **Motivation A**. On the other hand, some funds should be allocated as cash incentives to reinforce and reward occupant environmental behaviour, shown in the final BOEB model as **Motivation B**, however, this part of the BOEB final model can also include punishment and fines for behaviour that was not considered to be environmentally-friendly.

These motivational factors, together with simple and effective guidelines from BOs and industry professionals, can encourage building occupants to improve their environmental behaviour. Therefore, the final BOEB model can be effectively implemented if the governmental authorities are 'in line' with the green rating system's strategies and frameworks, with the goal of promoting environmental behaviour among their occupants. The benefit will be that the new structure of the used model by the authorities and LEED policy makers can be formulated integrating the revised version of the BOEB model proposed by this research. The final BOEB model can be also utilised within non-LEED-certified buildings with minor modifications, however what the exact changes are to be implemented to make it fit for any type of building is beyond the scope of this research study.

7.7 CHAPTER SUMMARY

The analysis of behaviour and energy use should receive the most attention as occupants can become aware of the outcome of their environmental behaviour and energy consumption. This approach can also help professionals and designers to design and modify the user-friendly systems more efficiently.

Knowledge and training together with motivational factors can improve occupant environmental behaviour towards more environmentally-friendly fashion.

Socio-cultural environment (**Motivation A**) and cash incentives (**Motivation B**) can change behaviour by making the situation in which occupants are encouraged to behave in an environmentally-friendly manner. Therefore, existence of cash incentives and effective socio-cultural environment can be led to better occupant environmental behaviour improvements as both factors are strong motivations.

Consideration of energy use and behaviour analysis as well as both motivations shown in the final BOEB model should be indicated clearly as requirements and points under '**After Occupancy Care**'. This process should become part of the post-occupancy and recommissioning phase of LEED certification process and to be adopted by governmental authorities as part of practices such as Soft Landings.

CHAPTER 8 - CONCLUSION

8.1 INTRODUCTION

Energy consumption in many residential buildings became a critical issue that should be focused upon in order to move towards a green built environment and to mitigate global warming. Green rating systems such as Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Methodology (BREEAM) and Green Globe Canada and many others actively practicing in different regions of the world while they are all hoping to achieve potential energy savings, to reduce carbon emission, and to keep occupants satisfied. However, there is still a performance gap between as-designed and actual building energy consumption after operation. Occupant behaviour accounts as one of the major reasons behind the significant uncertainty regarding building energy use. Little is known about how or whether the occupants of these buildings cause the performance gap. A better understanding of occupant behaviour was needed in order to manage this uncertainty at a higher acceptable level. This study has therefore been dedicated to the topic of the influence upon a green building occupant behaviour.

The findings in this research rely on analysis of the data collected from four LEED-certified buildings in Dubai-UAE. Combining quantitative (survey) and qualitative (interview) datasets was an effective approach used by the researcher to understand reasons behind occupant behaviour, their level of involvement in their building environmental operation and factors that can possibly motivate them to behave in a more environmentally-friendly manner. After that the data was analysed using a Structural Equation Modelling (SEM) technique to investigate the interrelationships between the three unobserved variables known as occupant environmental Attitude, Knowledge and Behaviour (AKB). Findings suggest that the best fitting structural model shows signs of interrelationships between these three unobserved variables AKB, but there are still no significant interrelationships between them, which means there is a need for other factors to change occupant environmental behaviour.

After that the Building Occupant Environmental Behaviour (BOEB) model was developed on the basis of best fitting structural model while including other motivational factors such as: i) the socio-cultural environment (**Motivation A**), and ii) cash incentives (**Motivation B**) found in Chapter 2 and 4 to promote better environmental behaviour among occupants. Finally, the developed BOEB model was validated by six validators including: a) two academic researchers, b) one industry professional, and c) three building operators (BOs) in the UAE and Canada, in order to review the applicability of, and barriers to, the developed model. The validated BOEB model (Figure 7.1) is the final version of the model proposed by the researcher. The model can be used by LEED policy makers, industry professionals, governmental authorities and BOs to improve building occupant environmental behaviour (BOEB) in order to inform and influence their behaviour to adjust the actual energy consumption closer to the amount of consumption initially estimated by designers and professionals. This model confirms that in order to bridge the existing energy performance gap caused by building occupants, LEED professionals, authorities and BOs should be closely involved during design, construction and post-occupancy or operation phase similar to the practices known as Soft Landings discussed in Chapter 2. The steps of the BOEB model can be taken to achieve the requirement of LEED '**After Occupancy Care**' certification process.

8.2 RESEARCH HYPOTHESIS

This research provided information about the less than environmentally-friendly behaviour of the occupants in LEED-certified buildings in the UAE. The findings helped the researcher to uphold the hypothesis that *"the occupants of LEED-certified buildings are not knowledgeable and motivated to behave environmentally-friendly"* solely as a result of them living in LEED-certified buildings and as one might expect from the occupants in these kinds of buildings. This research finding serves to confirm that certifying buildings as 'green' or LEED-certified does not necessarily make their occupants 'green' or environmentally sensitive. The findings also revealed that the occupants don't behave in an environmentally-friendly fashion, as they don't have enough knowledge and motivation to become more environmentally responsible individuals. Therefore, there is a need of further involvements by LEED policy makers and industry professionals during '**After Occupancy Care**' phase.

8.3 KEY FINDINGS

<u>The key findings from the literature review:</u>

- Occupant behaviour accounts as one of the major reasons of significant uncertainty in green/ LEED-certified buildings energy use.

- LEED still did not show a great deal of involvement and care for occupant behaviour during the LEED-building after occupancy phase.
- The findings show the occupants are forgiving towards energy conservation practices in green buildings, although they have higher satisfaction levels in LEED-certified/green buildings than in conventional/non-green buildings.

The key findings from the pilot study:

- Occupants in LEED-certified/green buildings demonstrate no more environmentally-friendly behaviour than those living in conventional/non-green buildings.

The key findings from the main research study (questionnaire survey and interviews):

- A growing number of LEED-certified buildings in the UAE are being designed to explicitly enable users to promote sustainable lifestyles. However, their occupants seem not to have received proper education and/ or access to feedback systems and they were not well-informed about the opportunities and capabilities of the building's energy-efficient and/or technology-oriented systems. The majority of occupants mentioned that they either have not received enough information, or the information was so complicated, it was rendered impossible for them to understand.
- Despite the fact that more than 80% of the occupants are well-educated and half of them have a high level of awareness of sustainability, that awareness has not been translated into environmentally-friendly behaviour.
- Technology-oriented systems, green approaches and LEED certification although make the buildings capable but do not necessarily lead to occupant greenness and positive environmental behaviour. These technology-oriented systems do not automatically improve performance in terms of energy use reduction, as the building itself is not the end-user.
- This study has also demonstrated that LEED-certified buildings need a higher level of engagement from those involved such as occupants, BOs, industry professionals, the governmental authorities and LEED policy makers.
- The current roles and duties of the occupants appear to be passive, however, the operation team seems to be more active but lacking in education or skills in operating and raising awareness among occupants effectively. BOs need to understand the significance of environmentally-friendly behaviour in maintaining the environmental performance of the

green building occupants. They also need to be able to understand how the building management system can operate efficiently.

- Based on the interview findings, the interrelationship between behavioural change and motivation is confirmed when there is a socio-cultural environment (**Motivation A**) or financial incentives (**Motivation B**), occupant behaviour can be improved towards more environmentally-friendly fashion.
- As with having industry and LEED professionals during the construction phase, there should be LEED professionals in place and trained to operate such buildings. In the other word, industry professionals should be involved throughout the building lifecycle.
- *In conclusion*: Matching technology, management sophistication, understanding roles, social organisation, and interactions among occupants, BOs, policy makers, the governmental authorities and industry professionals, can combine to constitute a powerful major avenue through which appropriate environmentally sensitive behaviours can be encouraged.

The key findings from Structural Equation Modelling (SEM) results:

- A good model fit has been developed and reviewed, but the interrelationships among the three latent variables AKB were not significant.
- Occupant knowledge and attitude did not necessarily lead those individuals to behave in an environmentally-friendly manner.
- Other than the interrelationships extracted and simplified from the best structural model fit in Chapter 5, there are many other factors that should be added to the model to alter occupant behaviour toward environmentally-friendly fashion.

The key outcomes of the final BOEB model and its validation:

- Assessing the BOEB model in both Dubai-UAE and Toronto, Canada was another advantage which showed that researchers, industry professionals and BOs in both developing and developed countries are aware of the importance of occupant environmental behaviour inclusion in any green rating systems. However, they all agreed that there is no well implemented framework or model proposed by the LEED-certification process that includes occupant behaviour as a means of bridging the performance gap caused by occupants.

- All validators agreed that the BOEB model provided a logical process if showing the feedback loop coming from energy and behaviour analysis, including knowledge and motivation through feedback, which can improve occupant environmental behaviour.
- Some of the barriers to using the BOEB model were centred on having a time-consuming and costly evaluation and feedback process, which needed a well-trained team to manage and monitor it. On the other hand, lack of support and funds can significantly reduce the level of effectiveness of such model.
- There is a large potential to motivate occupants to behave environmentally-friendly by promoting a better socio-cultural environment (**Motivation A**) and providing financial incentives (**Motivation B**). This initiative needs involvement by LEED policy makers, industry professionals and governmental authorities. Cash incentive, rewards and punishments by authorities can change the occupant behaviour during a shorter path which can subsequently change their attitude and lifestyle over time.
- Finally, one way the LEED categories can be enhanced is by incorporating environmentally-friendly behaviour under management and operation categories. In fact, the inclusion of occupant environmental behaviour is very important in the process of green building design, especially when the aim is to promote an environmentally-friendly approach to achieve the potential energy savings. Inclusion of occupant behaviour within LEED categories as '**After Occupancy Care**' will also help occupants, BOs and industry professionals to become more educated, engaged, and mindful about the consequences of their actions and their environments, while this should become part of LEED categories for recertification during the post occupancy phase as below:

After Occupancy Care

➢ POE and analysis of behaviour	Required
➢ Analysis of energy use	Required
➢ Self and others monitoring (Socio-cultural environment, **Motivation A**)	3 Point
➢ Cash reward and punishment (**Motivation B**)	2 Points

8.4 FULFILLING THE RESEARCH AIM AND OBJECTIVES

Taking the five initial objectives of this research the following sections explain how these objectives were achieved:

Objective 1: *To review the development of green buildings and evaluate the impact of occupant environmental behaviour on green building performance.*

The literature review helped the researcher to understand more about: i) sustainable buildings, ii) building energy performance gap, iii) environmental evaluation tools and green rating systems, and finally iv) LEED categories benefits and drawbacks. The obtained information broadened the researcher's vision about the development of green buildings. In particular, a focus on the different factors that can increase the dissonance between predicted/ as-designed and actual energy performance of a building after occupation was facilitated. This dissonance is generally known as the 'performance gap', which can be caused by factors such as: a) environmental uncertainty, b) unsatisfactory quality of building elements and workmanship and finally c) building occupant environmental behaviour. More significantly, the study's findings revealed that there is no inclusion of occupant behaviour in the comprehensive evaluation technique during the occupancy phase of the LEED-certified buildings, while POE should be a crucial part of each rating system.

Objective 2: *To review the existing occupant behaviour models and frameworks.*

A literature review was conducted to investigate different factors that influence occupant behaviour within proposed models and frameworks. The researcher understood that changing environmental behaviour of occupants requires better understanding of their lifestyle, attitudes, needs, actions, and knowledge.

Objective 3: *To understand occupant environmental behaviour and to investigate the interrelationships between their environmental Attitude, Knowledge and Behaviour (AKB) within LEED-certified buildings.*

A pilot study was carried out with fifteen participants in a LEED-certified/green building and fifteen participants in a conventional/non-green building in Dubai-UAE to confirm that those residing in the LEED-certified buildings are not behaving in a more environmentally-friendly fashion than those living in non-green buildings. After that, the main research study was carried out with a bigger sample of two hundred and three occupants within four LEED-certified/green buildings in Dubai-UAE. Ten participants accepted to participate in interviews, to enable the researcher to understand the reasons behind certain environmental behaviour, as well as finding out the motivational factors that can encourage occupants to behave in a more environmentally-friendly manner. This part of the study also helped the researcher to identify observed variables for further analysis. Five building operators (BOs) from the same four LEED-certified buildings (two from one building) were also interviewed to enhance the investigation into the behaviour and involvement of occupants living in those buildings. These interviews were also helpful to understand the level of education and training provided to those staff operating / managing such buildings. On the other hand, BOs point of view on the level of occupant involvement in their building operation was investigated.

The collected data were then transferred to AMOS 22 for further analysis through SEM technique. The observed variables from three sections of the questionnaire related to latent variable AKB were selected to assess the interrelationships between the three mentioned latent variables. The best fitting SEM model outcome from this analysis was used as the basis to fulfill objective 4.

Objective 4: *To develop a Building Occupant Environmental Behaviour (BOEB) model.*

The developed BOEB model – Stage 1, was informed by the best fitting structural model verified in SEM. It was then developed based on different motivational factors found in the research analysis and results in this research study and the findings from the literature review.

Objective 5: *To validate the developed BOEB model and demonstrate its applicability.*

The developed BOEB model was then validated by total of six validators. The final BOEB model is the most suitable BOEB model version; the model that will be proposed by the researcher to the LEED policy makers, governmental authorities, industry professionals and BOs. The creation of a comprehensive validated BOEB model was the main aim of this PhD research study to monitor and improve occupant environmental behaviour under LEED certification process as '**After Occupancy Care**', while involving industry professionals to raise awareness and motivate occupants towards environmentally-friendly behaviour in order to bridge some of the buildings energy performance gap.

8.5 FINAL FEEDBACK

The summarized suggestions for the LEED certification process are:

- Building operation team members / management should be well-educated people, able to understand and follow the concept of environmentally-friendly behaviour and LEED guidelines. These attributes will enable such personnel to maintain proper building monitoring and controlling systems in order to gain the best feedback from occupant energy use and behavioural evaluations.
- The LEED-certification process should incorporate occupant environmental behaviour and POEs as part of the LEED categories. Inclusion of occupant behaviour can help LEED professionals to review, examine and update design requirements, informed by feedback from POEs through both surveys and interviews with occupants. This process can adopt the final BOEB model to review the following items every few years during the recommissioning certification procedure known as '**After Occupancy Care**' category.

8.6 CONTRIBUTION AND SIGNIFICANCE OF THIS RESEARCH STUDY

The main contribution of this research study is to outline the positive influence that the final BOEB model can have on the current LEED certification process. On their own LEED certification and categories are insufficient to promote environmentally-friendly behaviour among occupants. Therefore, LEED policy makers and professionals can deploy the final BOEB model, with the inclusion of occupant behaviour which will help to raise awareness about the potential effectiveness of proposed design requirements and user-friendly systems. The buildings should be certified for the post-occupancy phase (recommissioning) while gaining the points under '**After Occupancy Care**' category.

This research has contributed to both theory and practice with proposing the implementation of the BOEB model for improving building occupant environmental behaviour. For contributions to theory, the proposed research will provide a new approach through an extensive critical literature review on the interrelationships between attitudes and behaviour and the impact that knowledge and motivation can have on behaviour. The validated final BOEB model (Figure 7.1) is applicable in the UAE if the governmental authorities support green rating system's strategies and frameworks to overcome the barriers in order to promote and encourage appropriate environmentally-friendly behaviour among their building occupants. It can also be further deployed by LEED policy makers and to be revised accordingly based on the outcomes as a prototype to support environmentally-friendly and energy conservation practices. The BOEB model can help change the general approaches of green agencies, governmental authorities, and related professionals for broadening current Post Occupancy Evaluation (POE) methods. Future initiatives should include a wider range of behavioural, socio-psychological and economic factors in their POE process; achievable through continuous monitoring and model changing. The industry policy makers and professionals can also make the necessary provisions and provide both motives and rewards for occupant environmental behaviour improvements within their future practices and developments similar to Soft Landings practices.

Finally, this doctoral research has highlighted the effectiveness of the evaluation of building occupant environmental behaviour, through the education and motivation model, as a starting point that showed the areas in which the LEED categories can be enhanced. The inclusion of occupant environmental behaviours may serve to highlight variations in different regions due to differences in socio-cultural approaches and beliefs. The important message is that while it is significant to design and construct buildings that are capable of saving energy, the environmental performance of their occupants can be jeopardised without training and motivating those occupants to engage in maintaining an acceptable level of greenness and adapting to future technological changes. As a result, occupant-system engagement requires collaboration and motivation, as well as involvement from: a) occupants, b) building operators, c) designers, d) investors, e) green agencies and f) governmental authorities. It is an interesting thought to contemplate that all these parties' approaches might be totally different from region to region.

This research will be of interest to academics, researchers, LEED policy makers, designers, constructors, governmental authorities, and all those who are involved in the planning, design, construction, operation and POEs process of the built environment in the UAE and the many other countries in which LEED-certified buildings are constructed.

Results will be published and presented at key conferences and significant journals in the hope that this research will make a strong contribution to the overall LEED-certification process by inviting decision-makers to share with them how the proposed final BOEB model can positively be efficient on building occupant environmental behaviour.

8.7 STRENGTH AND LIMITATIONS

In this study, evaluating data collected through both quantitative and qualitative methods from two hundred and three occupants in four LEED-certified buildings generated a rich and strong data set that helped the researcher to investigate and identify the motivational factors that could potentially change the occupant behaviour.

Limitation in the current research is that generalizing the final BOEB model is a challenging task. The final BOEB model should be part of the solution to the problem, and not the only solution. It is hoped that the model can be applicable in all regions of the world with some modifications based on regional differences and occupant preferences.

8.8 AVENUES FOR FUTURE RESEARCH

This thesis has examined building occupant environmental AKB, satisfaction and education in relation to their experiences in their LEED-certified buildings in the UAE. Further research in the area of social dynamics of positive environmental behaviour represents a new and exciting area of inquiry.

Future work could focus on constructing an understanding of how occupants learn about buildings, in order to design effective motivational-educational feedback mechanisms. Such mechanisms will help to explain ways to engage occupants in environmentally-friendly activities through policies and green building guidelines. Such an initiative will also help occupants to develop a more meaningful engagement in green and energy savings practices.

The tension between technology-oriented smartness and occupant-oriented smartness in LEED-certified buildings represents an important area of research with implications for the designing of user-friendly green buildings. Therefore, further research is needed to better understand how to balance intelligent motivation and engagement in the context of green buildings. Areas also ripe for investigation include: i) adapting innovations and appropriate home characteristics to occupant behaviour and ii) how to model those behaviour while simulating the building design, while all initiatives being informed by the possibility that occupant behaviour could be totally different from region to region.

It is worth elaborating on an insight featured in Chapter 4 that in order to gather the highest quality feedback about occupant environmental behaviour, POEs run by professionals should triangulate data as much as possible by comparing questionnaire survey's and interviews results.

Several questions can be asked which are of relevance to future research that may be perceived as a continuation to the current research study's findings.

- Do real-time POEs, feedback, guidelines and policies lead to occupant better understanding of their building?
- If occupants behave in an environmentally-friendly way can those 'greener' people increase the efficiency of the green buildings they live in, thereby bridging the proportion of performance gap?
- What are the types of motivation that can change people's attitudes and lifestyles in the quickest way in different regions of the world?
- How can professionals model occupant behaviour including motivation while designing green buildings to reduce the performance gap between as-designed and after-operation rates of energy consumption?
- What will an optimal BOEB model look like while adopting by LEED certification process?

The final BOEB model might be utilized within non-LEED-certified buildings with minor modification such as: i) removing LEED policy makers from the deployment part of the model and transfer that responsibility to building operators and governmental authorities as well as ii) proposing technology-oriented systems and green approaches by industry professionals and building designers under the national energy codes for buildings in different regions. However, what the exact changes are to be implemented is beyond the scope of this research and can be considered as the avenue for future research to answer to the following questions:

- What changes need to be done to the BOEB model to make it suitable for different regions/ countries?
- How can the final proposed BOEB model be employed by the occupants of non-LEED-certified buildings?

APPENDICES

- APPENDIX A – Cover letter for survey questions
- APPENDIX B – Survey questions

APPENDIX A – COVER LETTER FOR SURVEY QUESTIONS

Invitation letter to participants

Dear Residents,

VOLUNTEERS NEEDED for the Heriot University research study on "LEED-Certified/green building in the UAE"

Purpose: The overall purpose of this research study is to explore resident's experiences of living in these buildings.

- Participation will entail answering to the survey questions.
- It will take about 15 minutes.
- All answers will be made to maintain the confidentiality of participants and will remain anonymous.

Who can participate?

Participants must be:

- Adults above 18 years of age

If you decide to participate, you can contact Mrs. E. Nezamifar at (00971)050-9201712, and/or send the responses to the following e-mail addresses:

e.nezamifar@hw.ac.uk

elmira.nezami@yahoo.com

If you need further information, you may also email the Ph.D. supervisor Professor Ming Sun at m.sun@hw.ac.uk

APPENDIX B – SURVEY QUESTIONS

Section 1: General information about you

1. What is your age?

□30 or under □31-40 □41-50 □50 or greater

2. What is your gender?

□Female □Male

3. What is your level of education?

□No qualification □High School Diploma □Bachelor's degree □Master's degree or over

4. Do you own or rent the home?

□Tenant □Owner □Other, please specify………………

5. How many years have you lived in this building?

□Less than 1 year □1-3 years □More than 3 years

6. How many people live in your home (including you)?

□1 □2 □3 □4 □5 or more

<u>Section 2: Your attitude toward environmental issues</u>

<u>Select one answer only for each of the following questions</u>

7. What is your view on climate change?

□Climate change is a major threat to the world

□There is some threat to the world from climate change

□There is little threat to the world from climate change

□There is no evidence for climate change

□Don’t know

8. Which of the following statements do you agree with?

□Energy use in homes have a major impact on the environment and climate change

□Energy use in homes have a limited impact on the environment and climate change

□Energy use in homes have no impact on the environment and climate change

□Don’t know

9. Which of these bests describes how you feel about your current lifestyle and the environment?

□I’m happy with what I do now

□I’d like to do a bit more to help the environment

□I’d like to do a lot more to help the environment

□Don’t know

10. Do you think you are doing more, the same or less than you were doing 4 years ago to be environmentally-friendly?

□I do more

□I do the same

□I do less

□Don’t know

11. Please rank the following factors in order of importance when you choose your home? Write 1 for the most important factor; 2 for the second most important factor; 3 for the next most important one; the same for 4 and 5 and finally 6 for the least important factor.

It’s location	
External environment	
The size of the home	
It’s energy efficiency features	
Costs (in rent or to buy)	
Style of the building	

12. Have you ever heard of sustainable or green building?

□Yes □No □Don’t know

13. Have you noticed the term ‘green building’ or ‘LEED-certified building’ while choosing this building? Did this affect your choice of housing?

□Noticed it, understood it and it influenced my decision

□Noticed it, understood it, but it had no effect on my decision

□Noticed it but did not understand it

□Didn’t notice it

Section 3: Your Lifestyle and Behaviour

14. Is there reserved parking lot for hybrid cars?

□Yes □No □Don't know

15. Is there recycle bin in your building?

□Yes □No □Don't know

16. How often do you recycle?

…………………………………………	Constantly	Frequently	Occasionally	Never
Papers	□	□	□	□
Plastic pieces	□	□	□	□
Glass	□	□	□	□
Metal pieces	□	□	□	□
Carton Boxes	□	□	□	□

Water-saving:

17. How often do you do each of the following activities?

	Constantly	Frequently	Occasionally	Never
Use the washing machine economically	□	□	□	□
Use the dishwasher economically	□	□	□	□
Use less water in the toilets	□	□	□	□
Press both buttons on the WC flush	□	□	□	□
Take showers instead of baths	□	□	□	□
Turn tap off when brushing teeth	□	□	□	□

Energy-saving:

18. How often do you do each of the following activities?

	Constantly	Frequently	Occasionally	Never
Leave the appliances on standby mode	□	□	□	□
Turn off lights if they're not needed	□	□	□	□
Use low energy light bulbs	□	□	□	□
Use low energy labelled appliances	□	□	□	□
Set the thermostat for air conditioning	□	□	□	□
Keep the AC off when windows are open	□	□	□	□
Keep the windows open during the summertime	□	□	□	□
Keep the windows open during the wintertime	□	□	□	□
Close windows shades/ blinds	□	□	□	□
Control the doors/ windows airtightness	□	□	□	□

19. What type of bulbs are fixed for artificial lighting at your home?

□All lights are fitted with the Energy saving ESL/LED bulbs.

□Some lights are fitted with the Energy saving ESL/LED bulbs and some with traditional bulbs.

□All lights are fitted with the traditional normal bulbs.

□Don't know

20. How many hours do you use artificial lighting in a day?

□1-6 hours □7-12 hours □13-18 hours □19-24 hours

21. How many hours do you leave AC working in a summer day?

□Don’t use AC at all

□1-6 hours □7-12 hours □13-18 hours □19-24 hours

22. How many hours do you leave AC working in a winter day?

□Don’t use AC at all

□1-6 hours □7-12 hours □13-18 hours □19-24 hours

23. How often do you do each of the following activities?

……………………………………	Constantly	Frequently	Occasionally	Never
Walk or cycle to work/ supermarket	□	□	□	□
Use the public transportation	□	□	□	□

24. Which of these will encourage you to reduce your water and electricity consumption?

□Environmental and climate change concerns

□Energy bills reduction and receiving cash back on saving

□Both of the above

□None of the above

□Don’t know

Section 4: Your Level of Satisfaction with Indoor and Outdoor Environment

25. How satisfied are you with the following about your home?

	Strongly satisfied	Satisfied	Neutral	Unsatisfied	Strongly unsatisfied
Indoor air quality (fresh air & stuffiness)	□	□	□	□	□
Thermal comfort (ability to keep the home at a comfortable temperature level)	□	□	□	□	□
Acoustic comfort (No noise from neighbours & HVAC)	□	□	□	□	□
Lighting comfort (The amount of daylight)	□	□	□	□	□
Sufficient artificial lights	□	□	□	□	□
Building cleanliness	□	□	□	□	□
Maintenance and operation	□	□	□	□	□
Building design & quality	□	□	□	□	□

Recreational areas in the building	□	□	□	□	□
Green/LEED-certified building	□	□	□	□	□
Location	□	□	□	□	□
Interior size	□	□	□	□	□
Privacy	□	□	□	□	□
Safety & security	□	□	□	□	□
View to outside	□	□	□	□	□
Purchase or rental price	□	□	□	□	□
Low energy bills	□	□	□	□	□
Accessibility to public transport	□	□	□	□	□
Accessibility to work	□	□	□	□	□
Accessibility to supermarket and shopping centres	□	□	□	□	□
Sufficient garden and greenery space	□	□	□	□	□
Overall satisfaction with your home	□	□	□	□	□
Overall satisfaction with building	□	□	□	□	□

Section 5: Your Views on Management and Information strategies

26. Do you know if the Building Management System has installed in this building?

□Yes □No □Don't know

27. Does Building Manager or developer conduct energy management or Post Occupancy Evaluation (POE) survey?

□Yes □No □Don't know

28. Do you receive reminder or feedback about recycling strategies from building manager?

□Yes □No □Don't know

29. Have you received user guides/manuals at the time of renting or buying your home in this building which can cover issues such as energy and water use, recycling, etc.?

□Yes, I received a simple user guide/manual and understood it easily.

□Yes, I received a very complicated user guide/manual and couldn't understand it.

□No, I haven't received any guides/ manuals at the beginning and during my residency

□I don't remember

30. How satisfied are you with the information provided to you within the following aspects?

	Strongly satisfied	Satisfied	Neutral	Unsatisfied	Strongly unsatisfied
Day-to-day energy usage guide	□	□	□	□	□
Operation and maintenance guide	□	□	□	□	□
Emergency cases guide	□	□	□	□	□

31. Rank your preferred way of receiving information on advice of energy saving approaches at home? Write 1 for your most preferred way; 2 for the second most preferred way; 3 for the third preferred way; and 4 for the last preferred way. Please specify if you have any other way in your opinion.

Printed paper	
Electronically using email or the web	
Video	
Practical demonstration and workshop	
Others, please specify	

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